TEXILA AMERICAN UNIVERSITY

TEXILA INTERNATIONAL JOURNAL



TEXILA INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH

ISSN: 2520-3088

Volume 13, Issue 4

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art001

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Public Health Nutrition Implications of the 2024 Global School Meals Survey Data on School Meals in 26 Selected African Countries

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Cite this article as: K.R.L. Nyanungo. Public Health Nutrition Implications of the 2024 Global School Meals Survey Data on School Meals in 26 Selected African Countries. Texila Int J Acad Res. 2026;13 (4).
https://doi.org/10.21522/TIJAR.2014.13.04.Art001

Received: 02.09.2026
Accepted: 18.10.2026
Published: 30.10.2026

Article Type: Original Research

Abstract *It is argued that more could be achieved if African countries utilise the evidence from the 2024 Global School Meals Survey Report and other data sources to inform their practices, decision making and strategic resource allocation towards the prevention of nutrition-related noncommunicable diseases. If evidence is not consistently translated into decision making, strategic planning and implementation practice, all developmental efforts are unlikely to yield the intended results. Therefore, the incorporation of quantified targets and performance indicators for tracking and reporting is recognised as a major improvement in the transition from the Millenium Development Goals to the Sustainable Development Goals and the 2023 adoption of the school meals indicator 4.a.4 on the proportion of school attending children receiving school meals. This study examines the profiles of 26 African countries from out of the total 142 countries across all the continents whose data was captured in the 2024 Global School Meals Report. Data is extracted and analysed to establish the pattern from the 2024 Global Child Nutrition Survey indicators on school meal coverage, sources of funding, infrastructure, nutrition, complementary school health activities and employment. Based on observed trends among the selected 26 countries, recommendations are proposed towards the accelerated achievement of desired school meals targets and realisation of African Union objectives of using the home-grown school feeding approach.*

Keywords *Malnutrition, Micronutrient - Deficiency, Obesity, School-Meals.*

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Introduction

The increase in nutrition related challenges affecting the 5 to 19 year age range, predominantly composed of school going children and adolescents is of global concern as cost-benefit analysis studies have shown the urgency required to mediate against the likely consequences of malnutrition and its associated disease burden.

There is inadequate evidence on the prevalence and consequences of malnutrition among the 5 to 19 year old population, nearly 90% of whom live in low and middle income countries and constitute 27% of their national populations. Adequate evidence would inform efforts to improve the nutrition of children and adolescents in developing countries [1, 2].

Evidence shows a worrying prevalence of diet-related conditions that affect significant numbers of the world's population, with the realistic likelihood of developing noncommunicable diseases because everyone is at risk of either eating too little, for survival or too much. Prior to the COVID 19 pandemic, it was noted that most countries were not prepared to manage Type 2 diabetes and heart diseases despite evidence that estimated that 700 million people did not have enough food to eat every day, while 2 billion were overweight or obese [3].

Overweight and obesity are caused by excessive consumption of carbohydrates and, in most cases, inadequate intakes of essential fatty acids, vitamins and minerals due to poor quality diets [4].

With 391 million school-aged children affected worldwide, the significance of childhood and adolescent overweight and obesity is due the established association with the higher risk of developing life-threatening diseases in later life, hence the need for effective health promotion interventions to prevent and reverse the observed nutritional risk factors. It has therefore been argued that if no action is taken, the global impact of obesity-related health issues will be felt by the year 2035 as observed risk indicators could potentially impact health systems with serious economic impacts [4].

Accelerated progress can be achieved by providing health promotion, prevention and healthcare services among children and adolescents and transforming education systems into health promoting entities with systems for evidence generation through the Global School Health Standards [5].

Public health nutrition was declared as the promotion and maintenance of nutrition related health and well-being of populations through organized efforts and informed societal choices [6], leading to targeted global multisectoral and multidisciplinary actions towards eliminating iron, iodine, vitamin A and zinc deficiency, with evidence of positive impacts, hence the continuing efforts under the current Sustainable Development Goals [7].

Policy interventions have been recommended for low and middle income countries to urgently prevent and reverse observed trends in current evidence of the levels of malnutrition, pattern of overweight and obesity and significant levels of micronutrient deficiency (iodine vitamin A vitamin D folate and zinc) among their populations. Malnutrition has been linked to the eventual manifestation of hypertension, cardiometabolic disorders, diabetes mellitus, dementia and cancers. On the other hand, it has been predicted that micronutrient deficiencies may lead to poor pregnancy outcomes, poor child and adolescent growth and development as well as goitre, poor vision, skin lesions and some mental conditions [8].Undernutrition and anemia have been shown to have adverse effects during the first 1000 days of human life and are associated with increased risk of having short stature, ill health, cognitive impairment and reduced productivity at work as well as individual income throughout one’s life [2].

The provision of state-funded school meals followed earlier voluntary charity organisation

responses to child hunger and undernutrition in Europe since the 1740s. Examples include the 1948 policy measures on the provision of free nutritious and warm school meals in Finland and the 1997 statutory universal school meals coverage in Sweden [9, 10].

By 2012, the school feeding programme had reached 45 million children, adolescents and young adults at day care centres, kindergarten, elementary, high schools and colleges [11].

Recognising evidence of the multiple benefits, the African Union incorporated school meals in its Maputo Declaration on Agriculture and Food Security in 2003 and the Comprehensive Africa Agriculture Development Programme in 2014 [12], and its decision for all its member states to implement the home-grown school feeding programme as part of the Education Strategy for Africa [13].

The latter decision was inspired by the Brazilian experience of a sustainable government funded school feeding and nutrition programme that integrates multiple sectors in linking local food production to supply schools. That strategy integrated implementation with policy, regulatory frameworks and the overall multisectoral food and nutrition strategy, linking smallholder agriculture supplies to the food requirements for school meals ,using the curriculum to promote healthy lifestyles through the curriculum, and creating employment opportunities within communities.

However the actual school meal coverage in low and lower middle income countries was far too low to impact on the reduction of inequalities affecting global targets on the elimination of hunger, education, child health and nutrition and poverty eradication [14].

Several high level decisions calling for accelerated health and nutrition interventions through schools have been buttressed by convincing evidence on the benefits and cost of non-implementation.

For example, the United States adopted detailed implementation guidelines for the realisation of national investment returns from the eight components of the Comprehensive School Health Framework [15].

At the turn of the 21st century, an evidence-based approach was adopted for the cost-effective achievement of the Education for All was the Focusing Resources on Effective School Health (FRESH) through four prioritised core health -related components (i) school policies, (ii) safe water/sanitation (WASH), (iii) skills-based health education, and (iv) school-based health/nutrition services such as deworming, micronutrients [16, 17].

Between 2003 and 2024, periodic Global School Health Surveys (GSHS) have been conducted on 13 to 17 year old students. Such surveys help In order to identify country level behavioral risk and protective factors in countries and inform public health policy [18].

More recently, the 2024 Global School Meals Survey Report acknowledges the current limitations affecting the public availability of data on national school feeding programmes.

In an attempt to assess how effectively the health, wellbeing and academic achievement of students had been improved through the holistic Health Promoting School Framework approach, which includes school nutrition interventions, one study analysed data from 1443 sources (1345 schools and 98 districts). However, due to the inadequacy of data for meta-analysis, no conclusions could be drawn from the results [19].

While the Langford study highlighted data gaps, such challenges continue to affect the Health Promoting Schools Initiative due to limited coordination between the education and health sectors and the lack of monitoring and evaluation [20].

Standardised data is required for the school meals indicator, a multipronged intervention to impact on inequalities, social safety nets, food systems, zero hunger, nutritional, health and learning outcomes [21].

The scarcity of reliable school meals data includes the outdated, fragmented nature of the

available information. challenges in determining the actual coverage, quality and real impact of school meals over time. An integrated single platform for the harmonisation and standardisation of multiple data sources would better enable policy makers on key social protection decisions [22].

Building on the Global School Health Policies and Practices Survey (G-SHPPS) and the Assessment of National Educational Systems for Health (ANESH) Given the slow progress in reaching the health promoting school targets and, four United Nations agencies recognised the slow implementation progress and jointly developed the Global School Health Standards platform for monitoring and benchmark national performance against the global standards for health-promoting schools and supporting evidence -based decisions [23, 24].

The 2024 Global School Meals Survey report advised that the published data should be used for general information only due to the challenge of limited availability of data in the public domain. Furthermore, the reports indicated that 94% of the countries relied on school visits while 68% of the programs utilized paper-based electronic records for the monitoring of their school meal programmes with challenges inadequate resources including insufficient specialization among the assigned officers, weak monitoring protocols, coordination among the multiple, multisectoral implementers and complex designing of effective food delivery systems across each country [25].

Leveraging on digitally-enabled systems for tracking how the results are affecting the lives of intended beneficiaries, would improve decisions in planning resources for desired programme performance [26].

Automated School Management Systems could solve several identified challenges in the implementation of National Strategic Health Plans 2019-2028 (NHSP).

It is argued that the systematic data collection, analysis and utilisation can be enabled through the inclusion of real-time digital solutions under the Student Health Management module of School Management Systems [26]. One example for possible adaptation and upscaling is the School Feeding Monitoring System in Senegal (SASSE) which captures daily data entries from school canteens [27].

Since all countries already have education management, health information Management Information Systems and food security information systems, among other databases, it would be more cost-effective to emphasize integration and information sharing than investing in a dedicated school meals data management platform.

A multilevel social determinant approach is required for focused multisectoral, multidisciplinary collaborative actions towards the desired broader scale elimination of health disparities [28].

One study found that the barriers to the translation of evidence into practice are predominantly due to issues at the individual level including lack of knowledge and skills on how to conduct, organise, utilise and appraise research literature whilst organisational barriers were limited access to research evidence and lack of equipment [29].

Its however not clear how such barriers apply to the translation of school meals evidence into national and subnational decisions as well as implementation strategies at individual school levels.

Methodology

Data was extracted from 26 randomly selected African l country reports under the Global School Meals Survey that was conducted between November 2023 and July 2024 using data from the year beginning in January beginning 2022. Figure 1 shows the geographical distribution of the sampled countries.



Figure 1. Map showing Location of the 26 Selected Countries

Source: *United Nations, 2025*

For this study, selective data was extracted from the published Global School Meals Survey report as summarised in Table1.

Table1. Data Extracted from the 2024 Global School Meals Survey Report

Extracted Data	**Description**	**Measurement/Indicator**
Total coverage	Share of primary and secondary school-aged children that received food through their school	Percentage
	Primary school enrolled children received school food,	Percentage
	Share of school-aged children not enrolled	Percentage
	Enrolled in school but not fed	
Total national school feeding budget	Government	
	International Donors	
	Private sector	
	Domestic NGOs	
	Other Donors, including family and community contributions	
Infrastructure	Electricity	All
		Most
		Some
		Very few

		None
	Piped water	
	Clean water	
	Flush toilets	
	Dedicated eating spaces	
	Kitchens	
	Sport or physical play areas	
	Solar panels/solar power	
Nutrition	Nutritionists involved	Yes/No
	Objective to meet nutritional goals	
	Objective to reduce obesity	
	Limitation on food and beverage marketing	
Complementary Activities	Height measurement	
	Weight measurement	
Employment	Total number of cooks/caterers	

Results

The proportion of school-aged children fed through schools is calculated using the total number of children who are eligible for enrolment at primary and secondary school level in the country's population [25] and represented in Figure 2.

The highest coverage among the countries was recorded in Eswathini (98%), Rwanda (86%) Namibia (78%) and South Africa (72%), followed by Botswana (56%) and Sao Tome Principe (52%).

- Tanzania (41%) Ghana (36%), Zambia (35), Malawi (34%) and Benin (30%).
- In Benin (30%) and Zimbabwe (27%) the coverage was slightly above a quarter of school-aged children.
- Coverage rates below 20% were reported in Kenya, Angola, Madagascar, Nigeria, Uganda, South Sudan, Niger, Morocco, Tunisia, Nigeria and Congo.
- Cameroon (2%) Mozambique (5%), Niger (5%) and Congo (9%) had the lowest coverage.
- No school meal coverage figure was recorded for Somalia.

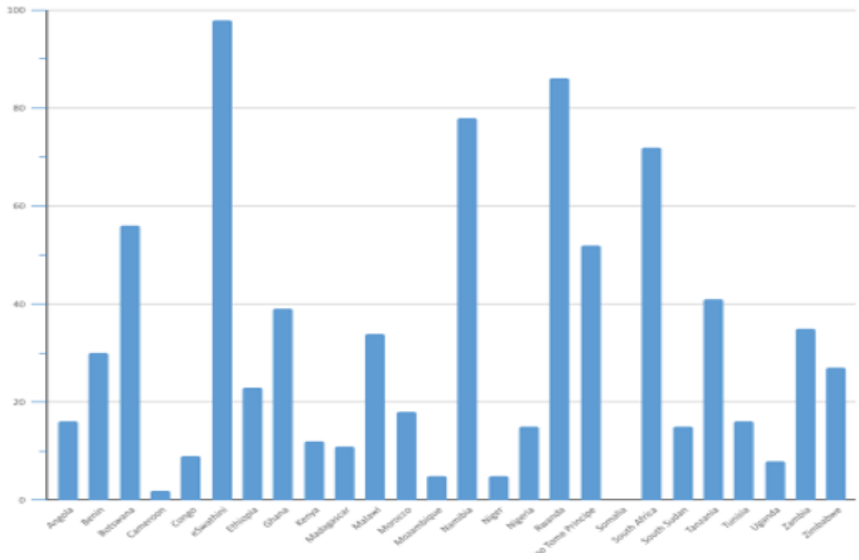


Figure 2. Graph showing the Proportion of Children Fed through School Meals

b. *Primary school enrolled children received school food* 4 out of the 26 countries reported 100% coverage, 3 reported feeding above 75% and 7 fed between 52% and 67% of their primary level enrolled children at school.

Between 20% and 49% school meal coverage was recorded in 7 of the countries and the remaining 5 countries reported coverage below 20%, with the lowest two having fed 9% and 3 % of their primary level enrolled children. The overall percentage of primary school enrolled children is shown in Figure 3.

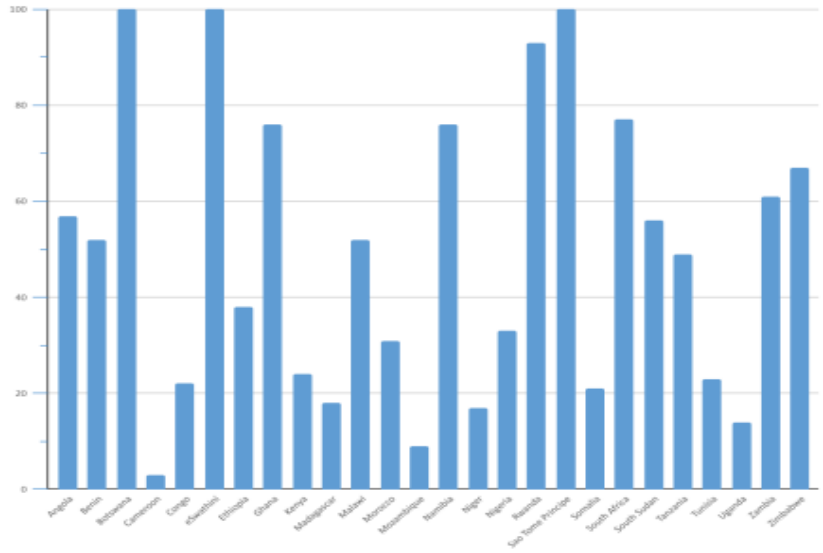


Figure 3. Graph showing the Percentage of Primary Enrolled Children Fed at Schools

The proportion of enrolled children who did not receive school meals in the selected 26 countries ranged from 1% to 88% as shown in Figure 4. 11 of the countries reported that between 50% and 88% of enrolled children did not receive any school meals Less than half the enrolled learners were left out in 15 countries. In 7 countries the school meals exclusion rate ranged between 31% and 49%. Approximately a quarter did not receive school meals in 4 countries. Less than 10% of enrolled children were not fed in 3 countries, which reflects almost universal coverage.

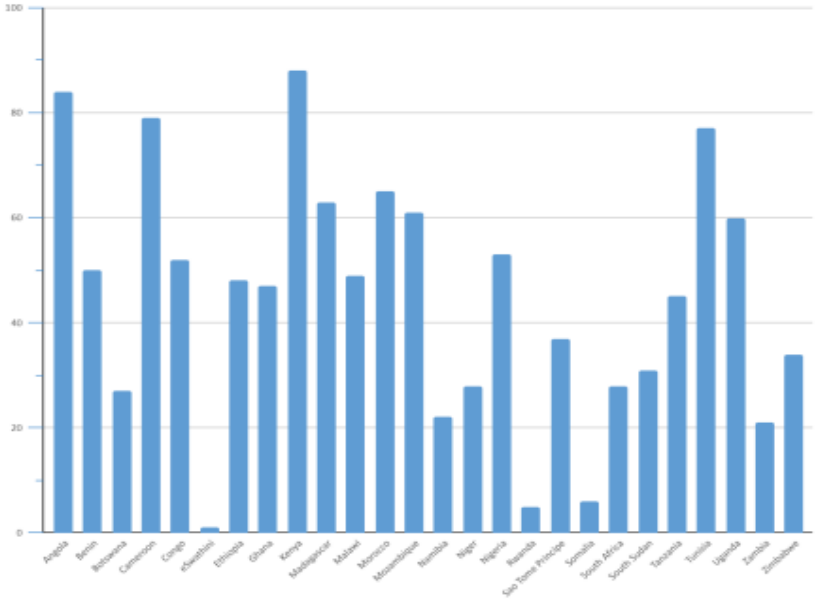


Figure 4. Graph showing Percentage of Enrolled Children not Fed at School

The proportion of school aged children who were excluded from school meals because they were not enrolled in school is shown in Figure 5. Among the 26 countries in Sub-Saharan Africa, less than 10% of school-aged children were not enrolled in school, namely, Eswatini (1%), Tunisia (7%) and Rwanda (9%). In some of the countries over half of the children were not attending school.93% of school-aged children in Somalia, 76% in Niger and 54% were not enrolled in. Less than half of the school-going aged population were excluded, significant proportions of children who were not enrolled during the year 2022 were recorded in Zambia (43%) Zimbabwe (39%) Congo (39%) Uganda, Nigeria (33%) Mozambique (34%) and Madagascar (28%) Benin (20%)and Cameroon 19 (%). No data on school-aged children who were not enrolled was provided for Angola, Kenya, Namibia and South Africa.

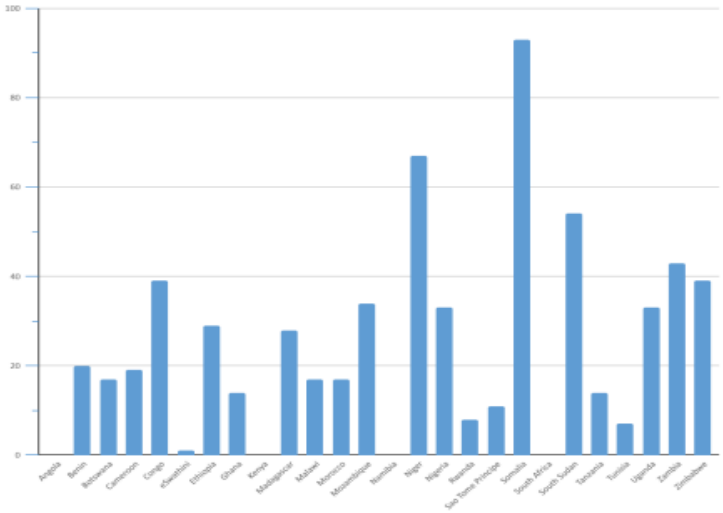


Figure 5. Graph showing the proportion of school-aged children who were not enrolled

Figure 6 shows the sources of funding for school meals among the sampled countries.

Out of the 26 selected African countries 8 (30.77%) of the national school meal programmes are 100% funded by governments. In 5 (19.2%) countries, International donors covered above 95% of the 1 budget. 22 (84.62%) of the countries recorded no private sector contribution at all. One country, Uganda, stood out with the highest level of contributions (76%) from other donors, including parents toward national school meals.

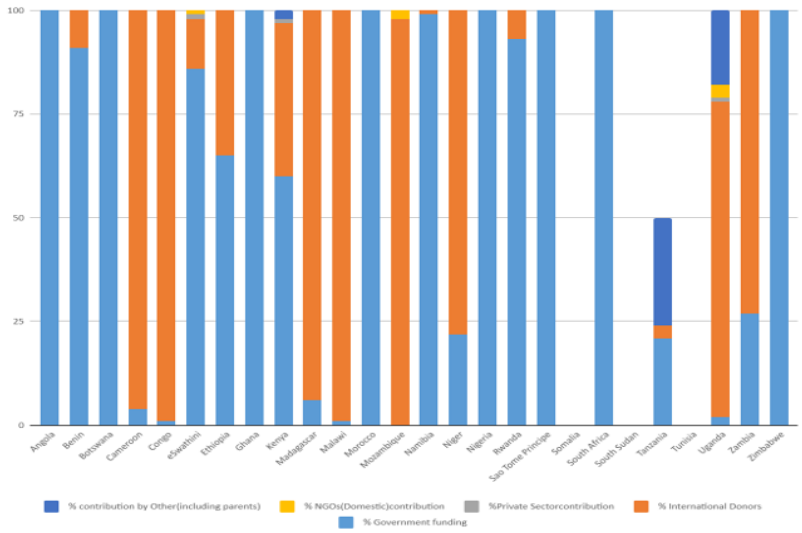


Figure 6. Graph showing Pattern of Contributions to National School Feeding Budgets

8% (2) out of the 26 countries reported that all their schools have electricity whilst 7 (27%) indicated that very few of theirs had electricity. 31% (8) of the sampled countries reported that their schools had electricity and 34% (9) recorded that some of their schools had electricity.

Figure 7 shows the geographical pattern of access to electricity in schools among the 26 selected African countries.

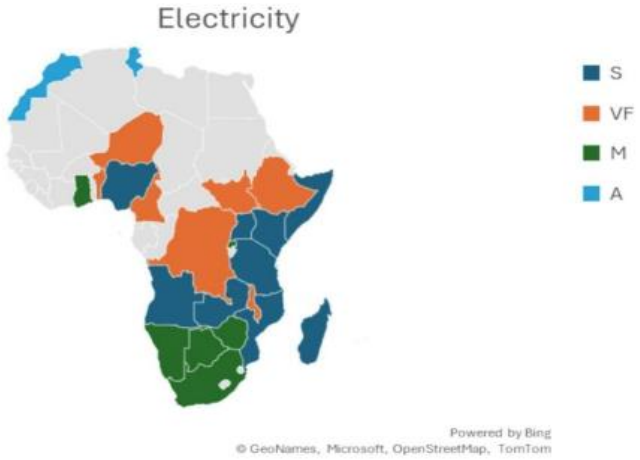


Figure 7. Map showing Geographical Pattern of Access to Electricity in Schools among 26 Selected Countries

In 3 (11.54%) of the selected 26 countries, it was reported that none of the schools had any form of solar energy, 19 (73.08%) countries reported that very few of their schools had solar panels/power, 3 (11.54%) indicated its availability at some of their schools. Only 1 country, Angola, recorded that solar panels/ power was available in most of its schools.

In 2 of the 26 countries, all schools had piped water. Most schools had it in 10 other countries and some in 8 of the countries were reported to have piped water. The remaining 6 countries recorded having very few schools accessing piped water.

In 2 (8%) countries, all the schools had clean water in contrast to 1 country out of the selected 26, South Sudan, that indicated that none of its schools had clean water while very few schools had clean water in 4 (15%) of the countries. 10 (38%) of the countries reported that most of their schools, and 9 (35%) recorded that some of their schools had access to clean water.

In 11 of the 26 countries the proportion of schools with flush toilets was reportedly very few, while 8 countries indicated that such toilets were in some of their schools.2 countries reported that all their schools had flush toilets and the remaining 5 countries recorded most of their schools having them.

In 15 (57.69%) of the countries, some of the schools had dedicated eating spaces while 3 (11.54%) reported most of their schools as having these. Very few schools were recorded as having dedicated eating spaces in 8 (30.77%) of the sampled 26 Sub-Saharan African countries.

All the schools in 5 (19.24%) countries had kitchens, most of the schools in 8 (30.77%) and some of the schools in 15 (57.69%) were reported to have kitchens for their school meals programmes. 5 (19.24%) countries indicated that very few of their schools had kitchens.

In 6 (23.08%) out of the 26 selected African countries, all the schools had sport or physical play areas. Most schools were recorded as having sport and physical play areas in 10 (38.46%) of the countries. 6 (23.08%) of the countries indicated that sport and physical play areas were available in some of their schools while very few schools had such facilities in 3 (11.54%) of the countries. Data from one country, Congo, indicated that none of the schools had any sport or physical play areas.

Nutrition

Nutritionists were reported to be involved in 23 (88.46%) of the national school feeding programmes. Out of the 26 countries, 12 (46%) reported having provided training for the cooks/caterers engaged in the preparation of school meals. Among the sampled countries, 22 (85%) responded that their school meals were aimed at meeting nutritional goals. Half of the countries indicated that their national school meals programmes were designed to reduce the challenge of overweight/obesity among children. 21 of the 26 countries (81%) reported having limited the marketing of certain foods and beverages on school grounds and/or to children. 15 (57.69%) of the countries reported data on the number of paid cooks/caterer jobs employed through school meals programmes. Half (50%) of the sampled countries reported conducting height and weight measurements on their enrolled children. In 22 (87%) of the countries were providing Physical Education.

Discussion

This paper examines and describes patterns from the extracted data on 26 out of 42 countries from the Africa region that participated in the 2024 Global School Meals Survey.

Of concern is the evidence that in some of the countries over half of the children were not attending school. This trend raises questions on why so many children and adolescents are not attracted to attend school when school meals are intended to incentivise school attendance.

On the other hand, evidence shows that in most of the countries, some of the enrolled children did not receive the school meals that some of them benefited from.

It is possible that such an incomplete coverage pattern may actually work against the goal of attracting all eligible children to attend school.

Moreover, school meals cannot be meaningfully implemented without incorporating actions to address documented evidence of common barriers to equitable access to education which include inadequate resources, competency gaps in teacher training, societal attitudes, and the low prioritisation of inclusive education in systemic policies [30].

The sustainability of school meal programmes requires predictable budgetary support. It is noted that although most school meal programmes in Europe were initiated by non-state players, governments later adopted policies and incorporated them into national budgets.

It is argued that the actual level of contribution by parents and communities could have been significantly underestimated in most of the countries as in-kind inputs are usually difficult to cost. A more detailed investigation may upscale such community resilient contributions towards sustainable school meals.

One of the capital investment requirements for the success of the multisectorally designed national school meals is the infrastructure requirements. The available data shows wide variations in the availability of electricity, solar power, kitchens, potable water, piped water and dedicated eating areas/caffetaria in African countries.

In view of the documented contribution of malnutrition, obesity/ overweight and micronutrient deficiency to the global disease burden, more research is recommended on measures to mainstream standardised training for food handlers and caterers in school meals programmes. Examples of training content for food handlers include topics on the nutrients necessary for humans' physical and mental growth and well-being, emphasis on food safety measures in order to guard against any risk of contamination or transmission of foodborne diseases throughout all the stages from food production, selection, handling, transportation, storage, preparation and consumption of the food [31], and a detailed fifty-two activity manual used in Brazilian schools [32] example and a training framework for food handlers in South Africa [33].

Among the sampled countries, 22 (85%) responded that their school meals were aimed at meeting nutritional goals, with half of them indicating that their national school meals programmes were designed to reduce the challenge of overweight/obesity among children.

In view of the known public health risk of poor nutritional habits, the urgency of nutritionists involvement at subnational implementation levels, closer to schools is indisputable.

One of the transformative education curriculum interventions is through the Sustainable Development Goal indicator 4.7, which is measured through the extent to which education for sustainable development has been mainstreamed into national education policies, curriculum, teacher education and learning assessment. Notably, a quarter or more of the greenhouse gas emissions that affect the health of all people and the entire planet are generated by the food system, consisting of food production, distribution, consumption and disposal [3].

Recognising the transformative impact of this indicator, recommendations have been made for strengthening ESD&GCED in teacher education, student assessment and monitoring and evaluation systems [34].

It is observed that the role of teachers could accelerate the goal of school meals programmes, thereby significantly impact on interrelated SDG indicators as school health and nutrition are implicitly part of the ESD&GCED framework. Several curriculum subjects could incorporate health promotion, physical education, sustainable food systems, sustainable consumption, environmental conservation and climate resilience and reforms in teacher education curriculum and approaches [3].

Conclusion and Recommendations

In summary, the analysis of data from selected African countries on school meal coverage, budgets, infrastructure, nutrition, complementary services and employment identified several trends that suggest the need for further research and review of current practices in the provision of school meals on the continent.

There is scope for incorporating realtime data into the decentralised, interlinked education, health, food security ,social protection management information systems and alignment of continuous professional development for all school meal implementers.

As learning does not only occur in schools, the increased participation of teachers, learners and communities is critical for achieving the Education for Sustainable Development and Global Citizenship Education (ESD&GCED) goals [35]. More research is therefore required into practical measures to accelerate the ESD&GCED thrust.

This paper supports the recommendation on strengthening collaboration among various stakeholders in inclusive education [30], with the addition that school meals should be part of the inclusive education thrust in order to achieve the intended impact.

Conflicts of Interest

The author declares no conflict of interest.

Acknowledgements

I acknowledge the Government of Zimbabwe for the insights that I gained as the national school feeding focal point from 2016 to 2024 and to the Global Child Nutrition Foundation for publishing the Global School Meals Survey reports.

Ethical Approval

Secondary data from a published source was used. No human participants were involved in the study, hence ethical approval was required.

Author Contribution

The author conceptualised the paper and extracted data from randomly selected country reports from the Africa region. wrote the

original draft and worked on the visualisation of the manuscript. The author has read and agreed to the published version of the manuscript.

Informed Consent

Not applicable.

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Funding

This research received no external funding.

Data Availability

Data was extracted from the 2024 School Meals Programs around the World Report. https://gcnf.org/global-survey/.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art002

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Quality of Routine Malaria Surveillance Data in Botswana's Highest-Burden Districts, 2023–2025

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Cite this article as: Khuteletso Bagapi, Galekgatlhe Bailey Balekang, Refilwe Yvonne Karabo, Ibrahim Bayoumy. Quality of Routine Malaria Surveillance Data in Botswana's Highest-Burden Districts, 2023–2025. Texila Int J Acad Res. 2026;13(4).
https://doi.org/10.21522/TIJAR.2014.13.04.Art002

Article Type: Original Research

Received: 01.09.2026
Accepted: 12.10.2026
Published: 30.10.2026

Abstract *High-quality malaria surveillance is essential for elimination. This study assessed routine malaria surveillance data quality in Botswana's highest-burden districts against WHO-recommended malaria elimination data-quality indicators and examined geographic and temporal variation during 2023–2025. A retrospective data-quality assessment used national Case-Based Surveillance (CBS) records and Integrated Disease Surveillance and Response (IDSR) aggregate counts. Districts were selected using a Pareto approach. Completeness, timeliness, internal consistency and CBS-IDSR agreement were assessed separately. Indicator proportions were summarized with 95% confidence intervals; geographic and annual differences were assessed using Pearson chi-square tests and multivariable logistic regression. The CBS dataset contained 3,393 records with valid analysis years. Okavango, Ngamiland and Chobe contributed 2,729 (80.4%) and formed the primary analytic population. Overall core-variable completeness was 79.5% (2,169/2,729), documented case investigation was 40.9% (1,117/2,729), notification within the day-level 24-hour approximation was 92.5% (2,409/2,603), investigation within 3 days among investigated cases was 58.0% (648/1,117), and internal consistency among evaluable records was 92.7% (825/890). Aggregate CBS-IDSR count agreement across the three districts was 95.7% (2,612 IDSR versus 2,729 CBS cases). Geographic differences were significant for all five case-level indicators ($p < 0.001$). Core completeness, documented investigation and investigation timeliness varied significantly by year, whereas notification timeliness ($p = 0.640$) and internal consistency ($p = 0.311$) did not vary significantly by year. Surveillance performance was heterogeneous across data-quality dimensions, districts and years. Timely notification and aggregate CBS-IDSR agreement were comparatively strong, whereas case-investigation documentation and timeliness remained important weaknesses requiring targeted surveillance strengthening.*

Keywords *Botswana, Completeness, Data Quality, Internal Consistency, Malaria Surveillance, Timeliness.*

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Introduction

Botswana's elimination efforts are guided by national and regional commitments, including the Southern African Development Community (SADC) malaria elimination agenda [1], and by the WHO's Global Technical Strategy for Malaria, which emphasizes surveillance as a core intervention and the use of high-quality data for program action [2].

High-quality surveillance is particularly important in elimination settings because incomplete, delayed, or discordant information can obscure transmission, delay case investigation, and weaken the targeting of response [3, 4]. The WHO Malaria Surveillance Assessment Toolkit provides a standardized and adaptable framework for assessing surveillance performance [5]. Under its data-quality subobjective, the toolkit assesses completeness, timeliness, consistency, and concordance. For elimination settings, it recommends case-based data, comparison with other systems that capture malaria cases and deaths, and disaggregation by administrative unit and time period; desk-level data quality assessment uses a suggested minimum of three years of data [5].

Data quality is multidimensional, and reliance on a single indicator can conceal weakness in a critical surveillance function. WHO routine health-information guidance assesses multiple dimensions, including completeness, timeliness, internal consistency, and external consistency [6, 7]. The malaria surveillance toolkit similarly treats completeness, timeliness, consistency, and concordance as distinct dimensions [5]. Studies of surveillance and routine health information systems also show that completeness and timeliness alone may not adequately represent overall system quality and that multidimensional approaches can provide a more informative assessment [5-10].

Accordingly, this study retained the WHO-aligned data-quality dimensions as separate outcomes rather than combining them into a study-derived composite index. Geographic and temporal variation was evaluated using indicator-specific estimates and inferential statistical comparisons, allowing differences in completeness, timeliness, and consistency to be directly quantified, while CBS-IDSR concordance was examined separately at the district-year level.

Despite Botswana's progress toward elimination, earlier studies documented persistent surveillance and response challenges, including incomplete case notification and limited household-level follow-up [11, 12]. Evidence remains limited on whether recent routine case-based malaria surveillance data in the highest burden districts achieve the quality needed for elimination and whether performance varies by geography and time. Therefore, this study applies the WHO malaria surveillance data-quality framework to a three-year period while retaining the underlying indicators for interpretation [5].

Objectives

1. To assess the performance of routine malaria surveillance data from Botswana's highest malaria burden districts against WHO-recommended malaria elimination data quality indicators for completeness, timeliness, consistency, and concordance during 2023–2025.
2. To assess geographic and temporal variation in malaria surveillance data quality indicators by district and year during 2023–2025.

Novelty and Contribution of the Study

This study applies the 2026 WHO Malaria Surveillance Assessment Toolkit to routine case-based malaria surveillance data in Botswana's highest-burden districts and formally evaluates geographic and temporal differences in indicator-specific data quality. Unlike approaches that collapse heterogeneous dimensions into a single composite, the analysis preserves completeness, timeliness,

consistency, and concordance as distinct surveillance functions and uses inferential statistics to identify where and when performance differs.

Materials and Methods

Study Setting

The study was conducted in Botswana and focused on districts with the highest malaria case burden during the study period. District selection was based on a Pareto approach using routine case-based surveillance (CBS) records from all reporting districts. Districts were ranked in descending order of confirmed malaria case burden, and districts contributing cumulatively at least 80% of reported cases were selected for the detailed data-quality assessment. This approach concentrated the assessment on areas contributing most to the national malaria case burden while applying an objective, prespecified selection criterion.

Study Design and Period

A retrospective cross-sectional data-quality assessment was conducted using routine malaria surveillance records for January 1, 2023, through December 31, 2025. The study uses a three-year analytic window consistent with the WHO toolkit recommendation for desk-level DQA and temporal consistency assessment. Data from 2022 were excluded because identified data-quality concerns could affect the reliability and comparability of surveillance indicators.

Data Sources

The primary source is Botswana malaria case-based surveillance (CBS) data. Integrated Disease Surveillance and Response (IDSR) aggregate case counts are used as a second reporting system for concordance assessment. The analysis is restricted to variables and indicators available in the supplied surveillance datasets and does not claim source-document validation where registers or case-investigation forms were not audited.

Study Population and Sampling

The study comprised confirmed malaria case records reported through the national CBS system during 2023–2025. Following district selection using the prespecified Pareto criterion, all eligible case records from the selected districts were included; therefore, no case-level sampling was performed within the selected districts. Records were eligible if they represented a confirmed malaria case, were reported during the analytic period, had a valid analysis year from 2023 through 2025, and originated from a selected district. Records with a missing or invalid analysis year were excluded because eligibility for the prespecified analytic period could not be established. The final numbers of records screened, excluded, and analyzed, together with the contribution of each selected district, are reported in the Results section.

Data Quality Assessment Framework

The assessment was aligned to the WHO Malaria Surveillance Assessment Toolkit, second edition (2026) [8]. The toolkit identified completeness, timeliness, consistency, and concordance as distinct data-quality dimensions for desk-level assessment. In elimination settings, the WHO recommended the extraction of case-based data and comparison with other systems that captured malaria cases and deaths. Indicators were selected a priori according to their applicability and availability in the Botswana CBS and IDSR datasets.

Completeness

Completeness was assessed using two prespecified indicators. Core-variable completeness was defined as the percentage of eligible cases with non-missing values for all 13 selected WHO-aligned variables available and applicable to all records: patient/system identifier, age, sex, nationality, diagnosis facility, district, symptom-onset date, diagnosis date, case-detection method, parasite species,

notification date, travel history, and final case classification. For cases reporting travel, the travel history item was considered complete only when a travel destination was documented. Documented case investigation was assessed separately from core-variable completeness. Missing investigation status was classified as no documented investigation. Invalid chronological sequences were assessed under temporal consistency rather than as missingness [5].

Timeliness

Timeliness was assessed using two indicators. Notification timeliness was calculated among records with both diagnosis and notification dates and was defined as a diagnosis-to-notification interval of 0-1 calendar days, a day-level approximation of the WHO 24–hour expectation because timestamps were unavailable [5]. Investigation timeliness was assessed among cases documented as investigated and was defined as investigation within 0–3 calendar days of diagnosis, using the current WHO toolkit reference pending confirmation of the Botswana national standard [5]. Missing or invalid investigation dates among cases documented as investigated were classified as not timely. Notification and investigation timeliness were estimated for the three selected districts combined and were additionally disaggregated by district and year to assess geographic and temporal variation.

Concordance

Concordance was assessed by comparing CBS and IDSR confirmed malaria case counts over identical district-year periods. Because record-level linkage was unavailable, the analysis used aggregate count agreement: 100 x [1 − sum|CBS–IDSR| / sum max (CBS, IDSR)]. For a single district-year, this reduced to 100 x [1 − |CBS-IDSR|/max (CBS, IDSR)]. This symmetric measure was study-derived and was not a WHO-defined score. WHO recommended a comparison of notified confirmed case numbers between parallel reporting systems in elimination settings [5].

Internal Consistency Checks

Temporal consistency was assessed using WHO-aligned logical chronology checks supported by the line list: symptom onset on or before diagnosis, diagnosis on or before notification, and notification on or before case investigation. The primary consistency outcome required all three checks to be evaluable and to pass. An extended check assessed case investigation on or before focus investigation when both dates were available. Implausible sequences were retained as data-quality failures rather than silently corrected [5]. A separate audit flagged records with at least one temporal inconsistency or a diagnosis year that did not match the recorded analysis year. These audit flags were used to characterize data-quality problems and were silently corrected in the analytic variables.

Assessment of Objectives

Objective 1 was assessed using the individual WHO-aligned indicators for completeness, timeliness, and temporal consistency, together with aggregate CBS–IDSR count agreement. Combined three-district case-level results were presented as numerators, denominators, percentages, and 95% confidence intervals. Objective 2 was assessed by comparing case-level indicators across district and year. The analysis did not use an overall data-quality composite index, thereby avoiding compensation for poor performance in one surveillance function by high performance in another.

Statistical Analysis

Descriptive statistics summarized case counts and data-quality indicators using numerators, denominators, percentages, and 95% confidence intervals. Pearson's chi-square test compared binary case-level indicators across the three selected districts and across years. Multivariable logistic regression models

were fitted separately for core-variable completeness, documented case investigation, notification within 24 hours, investigation within 3 days among investigated cases, and temporal consistency. Each model included district and year as categorical predictors, with Okavango and 2023 as reference categories. Adjusted odds ratios (aORs), 95% confidence intervals, and two-sided p-values were reported; $p < 0.05$ was considered statistically significant. Year was treated primarily as categorical because only three annual periods were available. The CBS-IDSR agreement was assessed descriptively from matched district-year aggregate case counts because record-level linkage was unavailable. District-by-year interactions and linear year tests were treated as secondary analyses.

Results

Study Population and Pareto Selection

The national CBS dataset contained 3,393 case records, all with valid analysis years from 2023 through 2025. Okavango accounted for 2,074 cases (61.1%), Ngamiland for 342 (10.1%) and Chobe for 313 (9.2%) Together, the three districts contributed 2,279 cases (80.4%) and constituted the primary analytic population (Table 1).

Table 1. Pareto Distribution of Malaria CBS Case Burden by District, BOTSWANA, 2023–2025

District	CBS cases	% of cases	Cumulative %	Selected
Okavango	2,074	61.1	61.1	Yes
Ngamiland	342	10.1	71.2	Yes
Chobe	313	9.2	80.4	Yes
Tutume	145	4.3	84.7	No
Bobirwa	91	2.7	87.4	No
Ghanzi	71	2.1	89.5	No
Boteti	55	1.6	91.1	No
Other districts	302	8.9	100.0	No

WHO-Aligned Data Quality Performance, 2023–2025

Across the three selected districts, core-variable completeness was 79.5% (2,169/2,729; 95% CI 77.9–81.0), documented case investigation was 40.9% (1,117/2,729; 95% CI 39.1–42.8), notification within the day-level 24–hour approximation was 92.5% (2,409/2,603; 95% CI 91.5–93.5), and investigation within 3 days among documented investigations was 58.0% (648/1,117; 95% CI 55.1–60.9). Internal consistency was 92.7% (825/890; 95% CI 90.8–94.2) among records with all dates required for the primary chronology checks. Aggregate CBS-IDSR count agreement across the three selected districts was 95.7%, with 2,612 IDSR cases compared with 2,729 CBS cases (Table 2). The corresponding evaluable proportions of the 2,729 eligible records were 100.0% for core completeness and documented investigation, 95.4% for notification timeliness, 40.9% for investigation timeliness, and 32.6% for the primary internal consistency outcome (Table 2).

Table 2. Overall WHO-aligned Data-quality Performance across the Three Selected High-burden Districts, Botswana, 2023–2025

Indicator	Combined three districts, n/N (%)	95% CI	Evaluable, n/N (%) of 2,729
Core-variable completeness	2,169/2,729 (79.5%)	77.9–81.0%	2,729/2,729 (100.0%)
Documented case investigation	1,117/2,729 (40.9%)	39.1–42.8%	2,729/2,729 (100.0%)
Notification within 24 h*	2,409/2,603 (92.5%)	91.5–93.5%	2,603/2,729 (95.4%)
Investigation within 3 days†	648/1,117 (58.0%)	55.1–60.9%	1,117/2,729 (40.9%)
Internal consistency‡	825/890 (92.7%)	90.8–94.2%	890/2,729 (32.6%)
CBS-IDSR aggregate count agreement	2,612/2,729 (95.7%)	Not applicable	Not applicable

*Notification within 24 hours was approximated as 0-1 calendar days because timestamps were unavailable.

†Investigation timeliness was assessed among cases documented as investigated.

‡Internal consistency required all three primary chronology checks to be evaluable and passed. CBS-IDSR agreement compared aggregate reported counts (IDSR/CBS) and did not represent individually matched cases; a binomial confidence interval was therefore not applicable. Evaluable n/N (%) reports the number of records contributing to each indicator relative to the 2,729 eligible records.

Individual completeness was high for most demographic and reporting variables. Symptom-onset date was complete in 87.4% of records, parasite species in 91.1%, notification date in 95.4%, and travel history in 98.7%. Investigation date was recorded in only 35.6% of records. Together with the 40.9% documented-investigation indicator, this identified investigation documentation as the principal completeness weakness (Table 3).

Table 3. Completeness of Individual Malaria Surveillance Variables across the Three Selected High-burden Districts, Botswana, 2023–2025

Variable	Complete, n/N	Completeness (%)
Patient/system identifier	2,729/2,729	100.0
Age	2,729/2,729	100.0
Sex	2,729/2,729	100.0
Nationality	2,723/2,729	99.8
Diagnosis facility	2,717/2,729	99.6
District	2,729/2,729	100.0
Symptom-onset date	2,385/2,729	87.4
Diagnosis date	2,729/2,729	100.0
Case-detection method	2,726/2,729	99.9
Parasite species	2,487/2,729	91.1
Notification date	2,604/2,729	95.4
Travel history*	2,693/2,729	98.7
Final case classification	2,729/2,729	100.0
Investigation date	971/2,729	35.6

*For cases reporting travel, travel history was considered complete only when a travel destination was also documented. Investigation date was reported separately because investigation is a conditional surveillance process and was not included in the universal core-variable completeness definition.

Internal Consistency

Internal consistency was high among records with sufficient dates for evaluation (Table 4). Among 890 records evaluable for the primary chronology outcome, 825 (92.7%) passed all three primary checks. Component pass rates were 97.8% (2,332/2,385) for symptom onset ≤ diagnosis, 99.0% (2,577/2,604) for diagnosis ≤ notification, 94.2% (914/970) for notification ≤ case investigation, and 97.4% (339/348) for case investigation ≤ focus investigation where evaluable. The substantially smaller denominators for investigation-related checks reflected the availability of the required dates and warrant cautious interpretation (Table 4).

Table 4. Internal Consistency of Malaria Surveillance Records across the Three Selected High-burden Districts, Botswana, 2023–2025

Consistency indicator	Passed, n/N	Pass rate (%)	Evaluable, n/N (%) of 2,729
Primary chronology outcome: all first three checks passed	825/890	92.7	890/2,729 (32.6%)
Symptom onset ≤ diagnosis	2,332/2,385	97.8	2,385/2,729 (87.4%)
Diagnosis ≤ notification	2,577/2,604	99.0	2,604/2,729 (95.4%)
Notification ≤ case investigation	914/970	94.2	970/2,729 (35.5%)
Case investigation ≤ focus investigation*	339/348	97.4	348/2,729 (12.8%)

District-year CBS-IDSR agreement varied despite the high combined agreement. Okavango showed agreement of 99.5% in 2023, 100.0% in 2024 and 98.5% in 2025. Agreement in Ngamiland was 96.1%, 69.0% and 77.1%, respectively, and in Chobe was 80.2%, 100.0% and 98.1%. The largest absolute discrepancy occurred in Ngamiland in 2025, when CBS recorded 236 cases and IDSR 182 cases, a difference of 54 cases (29.7% relative to IDSR) (Table 5).

Table 5. CBS-IDSR Aggregate Count Agreement and Discrepancy by District and Year, 2023–2025

Year	District	CBS Confirmed Cases	IDSR Confirmed Cases	Absolute Difference	Aggregate Agreement (%)
2023	Okavango	216	215	1	99.5%
2023	Ngamiland	77	74	3	96.1%
2023	Chobe	111	89	22	80.2%
2024	Okavango	154	154	0	100.0%
2024	Ngamiland	29	20	9	69.0%
2024	Chobe	41	41	0	100.0%
2025	Okavango	1,704	1,679	25	98.5%
2025	Ngamiland	236	182	54	77.1%
2025	Chobe	161	158	3	98.1%

CBS-IDSR agreement was interpreted as an aggregate reporting-system comparison rather than record-level concordance. The study-derived agreement percentage was not used as a WHO pass/fail threshold.

All primary data-quality indicators differed significantly across districts in unadjusted analyses (all Pearson chi-square $p < 0.001$). Core-variable completeness was 94.6% in

Okavango, 37.7% in Ngamiland and 24.6% in Chobe. Documented case investigation was 43.4%, 15.5% and 52.1%, respectively. Timely notification was 96.9% in Okavango, 77.3% in Ngamiland and 72.6% in Chobe. Among investigated cases, investigation within 3 days was 68.1% in Okavango, 24.5% in Ngamiland and 12.9% in Chobe. Internal consistency among evaluable records was 94.1%, 100.0% and 63.6%, respectively (Table 6).

Table 6. Geographic Variation in WHO-aligned Case-level Data-quality Indicators and Adjusted District Effects, 2023–2025

Indicator	District	n/N (%)	Pearson p	Adjusted effect vs Okavango	Adjusted p	Evaluable, n/N (%) of district total
Core-variable completeness	Okavango	1,963/2,074 (94.6)	<0.001	Reference	-	2,074/2,074 (100.0%)
	Ngamiland	129/342 (37.7)		aOR 0.034 (0.025−0.045)	<0.001	342/342 (100.0%)
	Chobe	77/313 (24.6)		aOR 0.017 (0.012−0.025)	<0.001	313/313 (100.0%)
Documented case investigation	Okavango	901/2,074 (43.4)	<0.001	Reference	-	2,074/2,074 (100.0%)
	Ngamiland	53/342 (15.5)		aOR 0.127 (0.089−0.182)	<0.001	342/342 (100.0%)
	Chobe	163/313 (52.1)		aOR 0.784 (0.593−1.036)	0.087	313/313 (100.0%)
Notification within 24 h*	Okavango	2,009/2,073 (96.9)	<0.001	Reference	-	2,073/2,074 (100.0%)
	Ngamiland	249/322 (77.3)		aOR 0.104 (0.072−0.150)	<0.001	322/342 (94.2%)
	Chobe	151/208 (72.6)		aOR 0.084 (0.056−0.125)	<0.001	208/313 (66.5%)
Investigation within 3 days†	Okavango	614/901 (68.1)	<0.001	Reference	-	901/2,074 (43.4%)
	Ngamiland	13/53 (24.5)		aOR 0.106 (0.054−0.207)	<0.001	53/342 (15.5%)
	Chobe	21/163 (12.9)		aOR 0.060 (0.036−0.098)	<0.001	163/313 (52.1%)
Internal consistency‡	Okavango	781/830 (94.1)	<0.001	Reference	-	830/2,074 (40.0%)
	Ngamiland	16/16 (100.0)		Not estimable§	-	16/342 (4.7%)
	Chobe	28/44 (63.6)		aOR 0.083 (0.040−0.174)	<0.001	44/313 (14.1%)

*Notification within 24 hours was a day-level approximation based on 0-1 calendar days from diagnosis to notification. †Investigation timeliness was assessed among cases documented as investigated. Okavango was the reference district.

Temporal Variation

Core-variable completeness increased from 56.9% in 2023 to 86.6% in 2024 and was 83.1% in 2025 ($p < 0.001$). Documented case investigation increased from 65.6% in 2023 to 85.3% in 2024 but fell to 31.5% in 2025 ($p < 0.001$). Timely notification remained high and did not differ significantly by year: 93.0% in 2023, 91.0% in 2024 and 92.7% in 2025 ($p = 0.640$). Among investigated cases, investigation within 3 days was 61.5% in 2023, 72.3% in 2024 and 52.5% in 2025 ($p < 0.001$). Internal consistency was 93.5%, 94.9% and 91.6%, respectively ($p = 0.311$) (Table 7).

Table 7. Temporal Variation in WHO-aligned Case-level Data-quality Indicators and Adjusted Year Effects, 2023–2025

Indicator	Year	n/N (%)	Pearson p	Adjusted effect vs 2023	Adjusted p	Evaluable, n/N (%) of year total
Core-variable completeness	2023	230/404 (56.9)	<0.001	Reference	-	404/404 (100.0%)
	2024	194/224 (86.6)		aOR 7.06 (4.09–12.18)	<0.001	224/224 (100.0%)
	2025	1,745/2,101 (83.1)		aOR 1.93 (1.39–2.67)	<0.001	2,101/2,101 (100.0%)
Documented case investigation	2023	265/404 (65.6)	<0.001	Reference	-	404/404 (100.0%)
	2024	191/224 (85.3)		aOR 2.97 (1.89–4.68)	<0.001	224/224 (100.0%)
	2025	661/2,101 (31.5)		aOR 0.172 (0.133–0.222)	<0.001	2,101/2,101 (100.0%)
Notification within 24 h*	2023	278/299 (93.0)	0.640	Reference	-	299/404 (74.0%)
	2024	202/222 (91.0)		aOR 0.872 (0.436–1.743)	0.699	222/224 (99.1%)
	2025	1,929/2,082 (92.7)		aOR 0.728 (0.438–1.212)	0.222	2,082/2,101 (99.1%)
Investigation within 3 days†	2023	163/265 (61.5)	<0.001	Reference	-	265/404 (65.6%)
	2024	138/191 (72.3)		aOR 1.55 (0.97–2.48)	0.069	191/224 (85.3%)
	2025	347/661 (52.5)		aOR 0.481 (0.342–0.676)	<0.001	661/2,101 (31.5%)
Internal consistency‡	2023	188/201 (93.5)	0.311	Reference	-	201/404 (49.8%)
	2024	167/176 (94.9)		aOR 2.13 (0.82–5.54)	0.119	176/224 (78.6%)
	2025	470/513 (91.6)		aOR 0.781 (0.401–1.519)	0.466	513/2,101 (24.4%)

*The focus-investigation chronology check was an extended consistency check and was evaluated only where both case-investigation and focus-investigation dates were available. The primary overall consistency outcome required the first three checks to be evaluable and passed. Ngamiland had complete prediction for the primary outcome (16/16 evaluable records passed), so its adjusted district effect was not estimable by standard logistic regression.

*Notification within 24 hours was a day-level approximation based on 0-1 calendar days.

†Investigation timeliness was assessed among cases documented as investigated. The year 2023 was the reference category.

Geographic and Temporal Variation in Internal Consistency

Internal consistency varied substantially by district but did not vary significantly by year. Overall, 781/830 (94.1%) evaluable records in Okavango, 16/16 (100.0%) in Ngamiland, and 28/44 (63.6%) in Chobe passed all three primary chronology checks (Pearson chi-square $p < 0.001$). Across years, 188/201 (93.5%) records passed in 2023, 167/176 (94.9%) in 2024, and 470/513 (91.6%) in 2025 (Pearson chi-square $p = 0.311$). The district-by-year interaction was not statistically significant ($p = 0.889$). Because all 16 evaluable Ngamiland records passed the primary consistency outcome, its district-specific adjusted odds ratio was not estimable using standard logistic regression. The small and selective district-year denominators warrant cautious interpretation (Table 8).

Table 8. Primary Internal Consistency Outcome by District and Year, Botswana, 2023–2025

District	Year	Passed, n/N	Pass rate (%)	Evaluable, n/N (%) of eligible records
Okavango	2023	178/189	94.2	189/216 (87.5%)
	2024	146/150	97.3	150/154 (97.4%)
	2025	457/491	93.1	491/1,704 (28.8%)
	Overall	781/830	94.1	830/2,074 (40.0%)
Ngamiland	2023	6/6	100.0	6/77 (7.8%)
	2024	6/6	100.0	6/29 (20.7%)
	2025	4/4	100.0	4/236 (1.7%)
	Overall	16/16	100.0	16/342 (4.7%)
Chobe	2023	4/6	66.7	6/111 (5.4%)
	2024	15/20	75.0	20/41 (48.8%)
	2025	9/18	50.0	18/161 (11.2%)
	Overall	28/44	63.6	44/313 (14.1%)
All districts	2023	188/201	93.5	201/404 (49.8%)
	2024	167/176	94.9	176/224 (78.6%)
	2025	470/513	91.6	513/2,101 (24.4%)
	Overall	825/890	92.7	890/2,729 (32.6%)

Statistical tests: overall district comparison, Pearson chi-square $p < 0.001$; overall year comparison, Pearson chi-square $p = 0.311$; district-by-year interaction from logistic regression, $p = 0.889$. Ngamiland adjusted district effect was not estimable because of complete prediction (16/16 passed).

Discussion

This study found substantial heterogeneity in malaria surveillance data quality across dimensions, districts, and years in Botswana's three highest-burden districts. For Objective 1, notification timeliness (92.5%), internal consistency among evaluable records (92.7%), and aggregate CBS-IDSR count agreement (95.7%) were comparatively strong. In contrast, only 40.9% of cases had a documented investigation, and 58.0% of documented investigations occurred within 3 days. Core-variable completeness was 79.5%. Preserving the WHO-aligned indicators separately made these contrasting surveillance functions visible rather than allowing strong performance in one dimension to offset poor performance in another [5, 6].

The most important operational weakness was case investigation. Although most demographic and reporting variables were highly complete, investigation dates were documented for only 35.6% of records, and

documented investigation was present for 40.9%. Notification was timely in 92.5% of evaluable cases, whereas only 58.0% of documented investigations occurred within three days. Internal consistency was high among evaluable records, but only 890/2,729 (32.6%) records were evaluable for the primary chronology outcome, emphasizing the need to interpret the 92.7% pass rate alongside its denominator. In an elimination setting, rapid notification alone is insufficient if cases are not subsequently investigated and classified in time to support interruption of transmission. Reactive case detection and investigation have been central to elimination surveillance in Eswatini and other low-transmission settings [18-21]. This is also consistent with the regional SADC elimination framework, in which timely, case-based surveillance and coordinated cross-border response are essential as transmission becomes increasingly focal [1].

For Objective 2, geographic differences were large and persisted after adjustment for year. Okavango had substantially higher core-variable completeness and timeliness than Ngamiland and Chobe. Compared with Okavango, adjusted odds of core completeness, timely notification, and timely investigation were markedly lower in both Ngamiland and Chobe. Ngamiland also had lower adjusted odds of documented investigation, whereas Chobe did not differ significantly from Okavango for that outcome. Internal consistency also differed by district among evaluable records: 94.1% in Okavango, 100.0% in Ngamiland, and 63.6% in Chobe ($p < 0.001$). However, the Ngamiland estimate was based on only 16 evaluable records, and its adjusted district effect was not estimable because all 16 passed the primary consistency outcome. Earlier Botswana studies documented the geographic concentration of malaria burden and persistent surveillance and response challenges during the country's progression toward elimination [14-16]. Comparable subnational heterogeneity has also been reported in Madagascar [22].

Temporal patterns were heterogeneous. Core-variable completeness improved from 56.9% in 2023 to 86.6% in 2024 and remained relatively high at 83.1% in 2025. Documented case investigation increased from 65.6% in 2023 to 85.3% in 2024 before falling sharply to 31.5% in 2025, and investigation timeliness also declined to 52.5% in 2025. In contrast, notification timeliness did not differ significantly across years ($p = 0.640$), and internal consistency among evaluable records also showed no significant annual difference (93.5% in 2023, 94.9% in 2024, and 91.6% in 2025; $p = 0.311$). The district-by-year interaction for internal consistency was also not statistically significant ($p = 0.889$). Because only three years were analyzed and the evaluable proportions for consistency varied by year, these findings represent year-to-year variation rather than evidence of a stable long-term trend. Temporal instability in malaria surveillance performance has also been documented elsewhere in Africa [23].

The observed district and year differences should not be attributed to specific operational causes without supporting program evidence. The Botswana literature has identified broader program challenges, including surveillance limitations, vector-control implementation gaps, and resource constraints [16, 17]. The recent malaria upsurge also prompted intensified surveillance and response activities [24].

Strengths include the use of routine operational surveillance data, a standardized WHO-aligned framework, explicit geographic and annual disaggregation, indicator-specific inferential analyses, and transparent reporting of the records evaluable for each indicator. The use of multivariable logistic regression allowed district differences to be estimated while accounting for year, and temporal differences to be estimated while accounting for district.

Several limitations should be considered. First, data from 2022 were excluded because of identified data-quality concerns; consequently, temporal analyses were restricted to three years and could not establish longer-term trends. Second, the available data contained calendar dates rather than timestamps, so notification within 24 hours was approximated as 0-1 calendar days. Third, internal consistency could only be assessed among records with all dates required for the primary checks, producing a smaller and potentially selective denominator; the evaluable proportion was 32.6% overall and varied substantially by district and year. Complete prediction in Ngamiland also prevented estimation of its standard logistic-regression district effect for consistency. Fourth, CBS-IDSR agreement was based on aggregate district-year counts rather than record-level linkage and therefore did not demonstrate that the same individual cases were captured in both systems. Fifth, the primary DQA focused on districts accounting for 80.4% of CBS records and may not represent lower-burden districts. Finally, this desk-level assessment did not independently verify accuracy against source registers or case-investigation forms.

Recommendations

The findings support prioritizing case-investigation completion and timeliness, particularly in Ngamiland and Chobe; routine reconciliation of CBS and IDSR; automated validation of chronological date sequences; district-level DQA dashboards that display completeness, timeliness, concordance, and consistency; and annual review of domain-specific performance. The large district differences also support targeted supervision rather than relying only on national aggregate indicators. These actions are consistent with WHO approaches to malaria surveillance assessment and routine data-quality assurance [4-6] and with evidence on interventions to improve routine health information system data quality and use [11-13].

Conclusion

During 2023–2025, malaria surveillance data quality in Botswana's three highest-burden districts showed a comparatively strong performance for notification timeliness, temporal consistency among evaluable records, and aggregate CBS-IDSR count agreement, but significant weaknesses in core-variable completeness, documented case investigation, and investigation timeliness. Performance varied substantially by district, with lower adjusted odds of several quality outcomes in Ngamiland and Chobe than in Okavango. Temporal changes were also heterogeneous: core-variable completeness improved, notification timeliness remained statistically stable, and case-investigation performance deteriorated in 2025. Routine monitoring should therefore retain the WHO-aligned indicators separately and prioritize district-specific gaps in investigation completion, investigation timeliness, and data completeness. Strengthening these functions is consistent with WHO elimination surveillance expectations and the regional SADC objective of maintaining sensitive, timely surveillance capable of detecting and responding to residual and imported transmission [1, 5, 20].

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgements

The authors acknowledge the Botswana National Malaria Programme for facilitating access to the data used in this study and thank Dr Phenyo Lekone and Mr Hari Krishnan for their guidance and support.

Ethical Approval

This study was ethically approved by the Ministry of Health -Botswana IRB on the 24th April,2026 (Ref Number; HPRD:6/14/1) as well as the Ministry of Local Government and

Traditional Affairs Research Unit (Ref Number CMLGTA 1/15/4/I/26) on 09th, July,2026). Ethical approval was given to use the routine National Malaria Programme data.

Author Contributions

The listed Authors have made significant contributions to the study and have gladly approved this final manuscript for its submission.

- **Khuteletso Bagapi:** Conceptualization of the study, study design, data request and ethical approval process, data analysis, manuscript drafting, and final revision.
- **Ibrahim Bayoumy:** Supervision of development of research proposal and preparation for ethical clearance.
- **Galekgatlhe Bailey Balekang:** Guided the preparation for statistical analysis, review of results, interpretation of results, manuscript proofreading, and contribution to final draft preparation.
- **Refilwe Yvonne Karabo:** Manuscript proofreading, and contribution to final draft preparation.

Data Availability

The data set used for this study has been approved for this study's academic purposes only and cannot be shared with third parties, however interested parties are permitted to make a separate request application to the Botswana Ministry of Health.

Funding

This study was self-sponsored by the lead author(student), since the author received no external funding for this study.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art003

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Constituency Development Fund Investments in Primary Health Care: Stakeholder Perspectives from Lufwanyama District, Zambia

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Cite this article as: Mukuka, J.M., Kooma, E.H. Constituency Development Fund Investments in Primary Health Care: Stakeholder Perspectives from Lufwanyama District, Zambia. Texila Int J Acad Res. 2026;13(4). https://doi.org/10.21522/TIJAR.2014.13.04.Art003

Received: 30.08.2026
Accepted: 25.09.2026
Published: 30.10.2026

Article Type: Original Research

Abstract *Zambia's Constituency Development Fund (CDF) provides a decentralised mechanism for financing local priorities, including projects that affect health service delivery. This qualitative single-case study explored stakeholder perspectives on the contribution of CDF investments to primary health care (PHC) in Lufwanyama District, Zambia. It examined stakeholders' understanding of CDF, their participation in implementation processes, and perceived factors that enable or constrain the contribution of Constituency Development Fund investments to Primary Health Care service delivery. In July 2026, 40 purposively selected participants from the local authority, District Health Office, health facilities and community structures took part in semi-structured key-informant and in-depth interviews. Relevant documents were also reviewed, and the data were analysed thematically using deductive and inductive procedures. Participants viewed CDF investments as important service-enabling inputs, particularly facility infrastructure, staff accommodation, maternity spaces, water and sanitation, ambulances, roads, facility rehabilitation and selected equipment. These investments were perceived to improve access, facility readiness and referral systems. Stakeholder-perceived enablers included timely funding, coordination, technical appraisal, community participation, monitoring, alignment with district health priorities and recurrent health-system support. Delayed implementation, procurement challenges, weak coordination, uneven feedback, staffing gaps, medicine shortages and limited recurrent support constrained the translation of completed projects into day-to-day PHC services. CDF should therefore be understood as an enabling financing pathway rather than a complete service-delivery intervention. Its contribution to PHC could be strengthened through alignment with district health priorities, technical review, recurrent health-system inputs, functionality-based monitoring and clearer community feedback and accountability mechanisms.*

Keywords *Constituency Development Fund, Decentralised Health Financing, Health Systems Strengthening, Primary Health Care, Service Delivery.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art003

Introduction

Primary health care forms the foundation of equitable, responsive and sustainable health systems by bringing essential services closer to communities. It requires an integrated, multisectoral approach combining clinical care, public health action, community participation and action on the social determinants of health [1]. The World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) identify governance, financing, workforce, infrastructure, medicines, information systems and community engagement as interdependent levers that strengthen Primary Health Care [2].

Rural households may experience long travel distances, poor road networks, seasonal isolation, limited transport options and fewer health workers, all of which can delay care seeking and reduce continuity of preventive, promotive, curative and rehabilitative services. These barriers are particularly significant for maternal and child health, communicable-disease control, emergency referrals, immunisation, disease surveillance, medicine availability and follow-up care for chronic conditions [3]. Strengthening Primary Health Care in such contexts therefore requires more than expanded clinical services; it also requires investment in the physical, logistical and governance conditions that make health facilities accessible, usable and trusted by the communities they serve [4, 5].

Zambia's National Health Strategic Plan 2022–2026 adopts this health-system framework and prioritises prevention, health promotion and services delivered closer to communities, supported by infrastructure, medicines, human resources, financing, leadership and governance [6]. These commitments highlight the need for financing mechanisms that respond to local service-delivery needs while remaining aligned with the wider health system. Decentralised financing mechanisms such as the Constituency Development Fund are therefore well positioned to complement central financing for Primary Health Care.

Zambia's decentralised policy direction is to deepen financing by moving resources, planning responsibility and accountability closer to communities. The Constituency Development Fund Act No. 1 of 2024 provides for the decentralisation of the management, disbursement, utilisation and accountability of the Fund, positioning Constituency Development Fund as a fiscal decentralisation mechanism through which community-identified needs can be prioritised, financed, implemented and accounted for within local governance structures [7]. The Fund is allocated across three components: community projects (60%), youth, women and community empowerment (20%), and secondary boarding school and skills development bursaries (20%) [8]. Although Constituency Development Fund is not a dedicated health financing instrument, its recent expansion has created greater fiscal space for communities and local authorities to finance health infrastructure and other service-enabling inputs [7, 8].

Constituency Development Fund is therefore relevant to Primary Health Care because it can respond to local service-delivery gaps that may take longer to address through centralised planning and sector-specific budgets. In practice, communities often identify needs that are closely tied to whether health services can function, including staff houses, maternity annexes, health posts, boreholes, sanitation facilities, bridges, feeder roads, solar power and transport support. Although these investments may be recorded as community projects rather than health-sector expenditure, they still affect whether Primary Health Care services are accessible, reliable and responsive to local expectations. This makes Constituency Development Fund a useful pathway for examining how decentralised development resources interact with district health systems, especially where health needs are clear at

community level but still require technical appraisal and recurrent support before they can become functional services [9].

For Primary Health Care, Constituency Development Fund-supported investments matter most when they strengthen connected service inputs such as infrastructure, staff accommodation, water and sanitation, transport, equipment, governance and community participation. International evidence identifies water, sanitation, hygiene, waste-management and electricity services as fundamental requirements for safe and quality care in health facilities, particularly in rural and resource-constrained settings [10, 11]. However, these inputs only become valuable when they are also linked to staffing, medicines, referral systems, maintenance and routine operating support [9]. The central concern in this study is that completed Constituency Development Fund projects do not automatically improve Primary Health Care service delivery, especially when they are not matched with wider health-system requirements. Stakeholders may also judge success differently: communities may value visible projects that bring services closer, local authorities may view completed projects as evidence of responsiveness, and health-sector actors may ask whether the projects improve service delivery through supporting staffing, utilities, equipment, referral capacity and recurrent operations.

Existing assessments of Constituency Development Fund often focus on allocation levels, visibility or completion, with less attention to access, readiness, responsiveness, referral capacity and perceived quality [21, 22]. This gap is particularly important in rural districts such as Lufwanyama, where Primary Health Care is strongly shaped by distance, staff accommodation shortages, water and sanitation needs, and referral and road-access constraints. Understanding this relationship requires attention to stakeholder perspectives because Constituency Development Fund-supported health investments are planned, approved, implemented and experienced by different actors who do not always define success in the same way.

To support multisectoral action and community participation, several actors are involved at district and community levels. Local authorities coordinate Constituency Development Fund processes and ensure compliance with public-finance and procurement procedures. District Health Offices provide technical guidance on service readiness, referral needs, staffing and facility standards, while health-facility staff assess whether investments improve day-to-day service delivery. Community members identify local priorities and judge whether projects reduce access barriers and respond to expressed needs. These perspectives are complementary but can create tension when roles are poorly defined, when visible community priorities differ from technical and data-informed health-sector priorities, or when completed infrastructure is not matched by medicines, equipment, health workers or maintenance resources.

The health systems strengthening literature shows that functional Primary Health Care depends on the interaction of service delivery arrangements, workforce, financing, information systems, medicines and technologies, and leadership and governance. Capital investments are therefore necessary, but they are not enough unless they are supported by other health system inputs [12]. Decentralisation literature makes a similar point: local financing can strengthen responsiveness, but only when local governance is matched by institutional capacity and accountability [12, 13], and when reforms are understood within their institutional, socio-economic and geographic context [14].

Evidence from Sub-Saharan Africa also shows that decentralisation produces mixed results when authority, resources and local capacity are not well aligned [15, 16].

Community participation can improve services when community voice is connected to formal planning, technical appraisal and feedback mechanisms; however, community influence weakens when accountability practices remain unclear [17, 18]. Evidence from Zambia similarly suggests that participation and social accountability are stronger when community actors, health workers and formal interfaces are clearly linked and feedback channels are functional [19, 20]. In Zambia, Constituency Development Fund is legally framed as a decentralised financing mechanism for community-identified priorities, but Zambia-specific studies show that its effectiveness depends on transparent planning, sound financial management, technical capacity and monitoring. These studies have identified bottlenecks in planning, monitoring, transparency and implementation [21, 22].

Broader work on health decentralisation in Zambia also points to difficulties in translating policy intent into meaningful community participation, partly because of constrained governance and weak stakeholder collaborative frameworks [23, 24]. Recent evidence strongly suggests that Constituency Development Fund may support maternal and child health, but its contribution depends on prioritisation, governance, implementation and sustainability [25]. Taken together, this literature suggests that Constituency Development Fund's contribution to Primary Health Care is conditional rather than automatic, and that there is still limited empirical evidence on how rural Zambian stakeholders experience Constituency Development Fund-supported investments as part of functional Primary Health Care service delivery.

Lufwanyama District provides a relevant case for examining these issues because rural Primary Health Care delivery in the district is shaped by dispersed settlements, variable facility readiness, transport and referral constraints, and continuing demand for health-related community projects. In such a context, Constituency Development Fund can potentially reduce inequities by financing locally prioritised investments that take safer and more functional health services closer to communities. At the same time, the district illustrates the risk that decentralised capital investment may remain disconnected from recurrent health-system requirements if planning, technical review and accountability mechanisms are weak. Examining stakeholder experiences in Lufwanyama therefore contributes context-specific evidence on how decentralised development financing is understood and operationalised within rural Primary Health Care service delivery.

The study was guided by three related theoretical perspectives. Health Systems Strengthening Theory helped explain why Constituency Development Fund-funded infrastructure requires staffing, medicines, referral systems and operating resources before it can function as part of Primary Health Care [2, 9]. Decentralisation and Decision Space Theories explained why community priority-setting and local-authority decision-making require technical capacity, institutional support and accountability to improve responsiveness [12-14]. Social accountability concepts framed the role of community voice, feedback and answerability when these are formally linked to planning and monitoring systems [17, 18]. Together, these perspectives position the Constituency Development Fund as an enabling financing pathway rather than a complete Primary Health Care intervention and provide an analytical basis for identifying factors that enable or constrain its contribution to service delivery.

The main objective was to examine stakeholder perspectives on how Constituency Development Fund investments contribute to functional Primary Health Care service delivery in Lufwanyama District, Zambia, and to identify perceived factors that enable or constrain the contribution of Constituency Development Fund investments to Primary

Health Care service delivery. The specific objectives were to: (1) explore stakeholder perspectives on how Constituency Development Fund investments contribute to functional Primary Health Care service delivery; (2) examine how stakeholder participation, technical appraisal and local governance influence the identification, prioritisation, implementation and monitoring of Constituency Development Fund-supported Primary Health Care investments; (3) identify perceived factors that enable or constrain the contribution of Constituency Development Fund investments to Primary Health Care service delivery; and (4) propose practical recommendations for strengthening the alignment of Constituency Development Fund investments with district health priorities, recurrent health-system inputs and community accountability mechanisms.

Materials and Methods

Study Design

This study used a qualitative single-case design informed by interpretivist and constructivist assumptions, with Lufwanyama District treated as the case [26-28]. The design was appropriate because the study aimed to understand how stakeholders made sense of Constituency Development Fund investments in relation to Primary Health Care support, participation, constraints and possible improvements. The focus was therefore on meanings, experiences and implementation conditions rather than on measuring project statistical outputs. Lufwanyama, a predominantly rural district in Copperbelt Province, Zambia, was selected because Primary Health Care access and readiness are shaped by long distances between communities and facilities, gaps in staff accommodation, water and sanitation needs, referral challenges, road-access constraints and limited operational support.

The single-case approach allowed the study to examine Constituency Development Fund-supported Primary Health Care investments as they occurred within a real district governance and service-delivery environment. Rather than separating Constituency Development Fund projects from the institutional setting in which they were planned and implemented, the design enabled attention to the interaction between local authority procedures, district health planning, facility-level service conditions and community expectations. This was important because the study's concern was not only whether projects had been completed, but how stakeholders interpreted their contribution to functional Primary Health Care in relation to access, readiness, coordination, recurrent support and accountability.

Study Population and Sampling

The study population included stakeholders with direct knowledge of Constituency Development Fund-supported Primary Health Care investments in Lufwanyama District. Participants were drawn from the Local Authority, District Health Office, health facilities and community structures, including Neighbourhood Health Committees (NHCs) and Ward Development Committees (WDCs). Forty participants were purposively sampled [26]: five Local Authority officials, five District Health Office officers, ten health-facility staff members or in-charges from five selected facilities, and twenty community representatives from the selected facility catchment areas.

Participants were eligible if they were aged 18 years or older, willing to provide informed consent, had served in their role or lived in the community for at least one year, and had direct involvement in or knowledge of Constituency Development Fund-supported Primary Health Care planning, implementation, monitoring, service delivery or community priority-setting. Participants were excluded if they did not have direct knowledge of Constituency Development Fund-supported health projects or were unable or unwilling to provide consent.

The selected facilities reflected variation in rural Primary Health Care delivery conditions, including distance from the district centre, catchment population, availability of staff accommodation, referral challenges, water and sanitation needs, and evidence of previous or ongoing Constituency Development Fund-supported health-related investments at the facility or within its catchment area [28, 29]. This variation enabled the study to capture both relatively better-served and more constrained service environments, thereby strengthening understanding of how Constituency Development Fund investments were experienced across different local implementation contexts.

Purposive sampling was used because the study required participants who could provide information-rich accounts of Constituency Development Fund planning, implementation and Primary Health Care service delivery rather than a statistically representative sample. Local Authority officials were selected for their knowledge of Constituency Development Fund administration, project approval, procurement and monitoring; DHO officers were included for their technical understanding of facility readiness, staffing, referral needs and health-sector priorities; health facility staff and in-charges were selected because they experienced the operational effects of Constituency Development Fund-supported investments; and community representatives were included because they reflected local perceptions of access, participation, responsiveness and satisfaction.

Data Collection

Data were collected using semi-structured key-informant interview (KII) guides, in-depth interview (IDI) guides and a document-review checklist. Each tool was aligned with the four study objectives. Key-informant interviews were conducted with Local Authority officials because of their roles in Constituency Development Fund planning, approval, procurement, implementation and monitoring. In-depth interviews were conducted with DHO officers, health-facility in-charges or staff, and community representatives. Interviews lasted approximately 20–30 minutes and were conducted in July 2026 in locations that ensured privacy and confidentiality [28, 29]. Written informed consent was obtained before each interview.

The interview guides were organised around the study objectives and included open-ended questions on understanding of Constituency Development Fund, perceived links between Constituency Development Fund investments and Primary Health Care service delivery, participation in priority-setting, technical appraisal, implementation experiences, monitoring, feedback, barriers and recommendations. Probing questions were used to obtain examples of specific projects and to clarify how participants distinguished between project completion and service functionality. Interviews were conducted in a manner that allowed participants to speak from their institutional or community experience while avoiding disclosure of personally identifiable information about service users or other individuals [29, 30].

With consent from participants, interviews were audio-recorded and supplemented with field notes. A document review checklist was used to extract information from Constituency Development Fund guidelines, district and facility planning documents, Integrated District Plans, reports and committee records. The review focused on project identification, approval, implementation status, monitoring and evidence of community participation, and helped triangulate participant accounts.

Document review complemented the interviews by providing contextual evidence on how Constituency Development Fund-supported health-related projects were identified, recorded and monitored. Reviewed documents were used to compare participant accounts with available administrative and

planning records, including references to project type, implementation stage, responsible structures and evidence of consultation [29]. The document review was not treated as a separate quantitative audit; instead, it supported triangulation and helped identify areas where stakeholder narratives converged with or differed from recorded planning and implementation information.

Data Analysis

Audio recordings were transcribed, checked for accuracy and organised by participant category and data source. The data were analysed thematically using Braun and Clarke's six-phase approach: familiarisation, initial coding, searching for themes, reviewing themes, defining and naming themes, and producing the final interpretation [31]. Coding combined deductive categories based on the four study objectives with inductive codes derived from participants' accounts. Saturation was assessed throughout data collection and analysis across participant categories and facilities and was considered reached when no new themes emerged concerning Constituency Development Fund financing, facility readiness, coordination, community responsiveness or health-system constraints [30].

The coding process began with repeated reading of transcripts and field notes to identify recurring ideas related to the four objectives. Deductive codes included categories such as stakeholder understanding, participation, technical appraisal, governance, facility readiness, access, referral capacity, recurrent inputs, implementation barriers and recommendations. Inductive codes were added when participants raised issues not fully captured by the initial framework, including feedback gaps, political visibility, post-completion functionality and perceived differences between visible infrastructure and usable services. Codes were then grouped into broader themes and checked against the original data to ensure they remained grounded in participant accounts [31].

Theme development involved comparing patterns across stakeholder groups and across the selected facility catchment areas. This helped identify whether a finding reflected a shared district-level concern or a perspective specific to a particular participant group. For example, community representatives tended to emphasise access, visibility and feedback, while health-sector participants more often emphasised staffing, equipment, utilities and recurrent inputs. Local Authority officials focused on procedures, approvals, procurement and accountability. Bringing these perspectives together enabled the analysis to interpret Constituency Development Fund's contribution to Primary Health Care as conditional on coordination among community priorities, local governance processes and health-system requirements.

Coding and theme development were documented in an audit trail that recorded code definitions, changes to the coding framework, theme development decisions and links between themes and supporting extracts. Themes were reviewed against the full dataset and compared across participant categories and document sources to assess coherence, distinctiveness and explanatory value.

Trustworthiness

Trustworthiness was strengthened through triangulation of interview and document-review evidence, comparison across stakeholder groups, an audit trail of sampling, coding and theme development, reflexive notes, and thick description of the study setting [32]. Data were anonymised using participant codes and stored securely with access limited to the researcher. The study followed applicable ethical procedures for health research in Zambia, guided by respect for persons, beneficence and justice; participants received information on study purpose, procedures, confidentiality and their right to withdraw

before providing written informed consent. Formal approvals are detailed under Ethical Approval below.

To reduce the risk of misinterpretation, emerging codes and themes were repeatedly compared against original transcripts, field notes and document-review extracts. Attention was paid to similarities and differences across Local Authority officials, DHO officers, facility staff and community representatives, since each group occupied a different position in the Constituency Development Fund-Primary Health Care implementation chain. This comparative reading helped distinguish shared concerns from category-specific perspectives and supported a more balanced interpretation of the findings [32].

Reflexivity was maintained throughout data collection and analysis by noting how the researcher's assumptions about decentralised financing, Primary Health Care needs and community participation could influence interpretation. Field notes were used to record contextual observations, interview conditions and emerging reflections after data collection sessions. During analysis, these reflections helped distinguish participant meanings from the researcher's prior expectations and supported transparent interpretation of how Constituency Development Fund was experienced across administrative, health-sector and community positions.

Results

Findings are presented in line with the four study objectives. Participants represented four stakeholder categories: Local Authority officials, DHO officers, health facility staff or in-charges, and community representatives.

Stakeholder Perspectives on Constituency Development Fund Investments in Primary Health Care Service Delivery

Stakeholders most often linked Constituency Development Fund to investments such as health facility infrastructure, staff accommodation, maternity spaces, water and sanitation, facility rehabilitation, road rehabilitation, ambulances, solar power, furniture and selected equipment. They valued these investments because they reduced practical barriers to Primary Health Care, improved facility readiness and supported referral services. Participants generally saw Constituency Development Fund as strengthening the conditions needed for service delivery rather than providing clinical services directly.

In rural settings, these conditions included shorter travel distances, better staff accommodation, improved water and sanitation, more space for maternity care, stronger referral systems, and basic infrastructure and equipment. For example, road improvements, together with bridge construction, were viewed as service-enabling investments because they connected communities, health posts, health centres and referral facilities more reliably, particularly during the rainy season, and supported more consistent movement of medicines, vaccines and other commodities to lower-level facilities. Ambulances were identified as a critical complement, reducing delays in moving emergency cases, pregnant women with complications and critically ill patients to higher-level care, as a DHO officer explained:

> *"For facilities in hard-to-reach areas, medicines do not always arrive on time because the roads become bad, especially during the rainy season. Even when supplies are available at district level, reaching some health posts can take longer than expected."*
>
> — DHO officer, IDI-5

Solar power for cold-chain equipment, computers for data management, and lighting for security and night emergencies were also highlighted, alongside staff accommodation and furniture, as contributors to facility readiness. Water, sanitation, hygiene, waste-management and electricity services were

described as fundamental requirements for safe and quality care in health facilities, particularly in rural and resource-constrained settings. A health facility in-charge described how these investments improved day-to-day service conditions:

"At this facility, staff houses, lighting and simple furniture have made a big difference because we are now staying within the clinic premises and patients can be attended to properly, even during the night."

— Health facility in-charge, IDI-6

Stakeholders did not define Constituency Development Fund's contribution to Primary Health Care in the same way. Community representatives tended to emphasise proximity and visible improvements. Local Authority officials often focused on whether projects were completed on time and responded to community demand. Health-sector participants judged investments by whether they improved readiness, referral capacity, staffing and continuity of routine services. As one facility in-charge observed, a community may celebrate a new structure because it is visible, while facility staff may ask whether it has enough staff, water, power and supplies. Overall, stakeholders viewed Constituency Development Fund as useful for Primary Health Care, but they also stressed that its value depended on whether projects became usable service inputs rather than visible structures alone.

"When the health worker stays near the facility, people have more confidence because they know someone can attend to emergencies even after normal working hours. Staff housing is therefore not just a comfort issue; it affects access."

— Health facility in-charge, IDI-7

Participants further noted that the value of Constituency Development Fund-supported infrastructure was greater when investments addressed multiple bottlenecks simultaneously. A staff house, for example, was viewed not only as accommodation but also as a means of improving staff retention, after-hours availability and the perceived reliability of the facility. Water and sanitation investments were linked to infection prevention, maternity care, patient dignity and staff working conditions. Participants also associated water-supply projects with animal health, household gardening, income generation and nutrition. These accounts show that stakeholders judged Constituency Development Fund contributions not solely by physical completion but by whether investments supported routine service continuity, reduced barriers experienced by patients and providers, and contributed to wider community health.

Participation, Technical Appraisal and Local Governance

Participants reported that community-level involvement occurred mainly through the identification of needs at community and ward levels, engagement with local authority structures, and consultation with health-sector actors. Community representatives viewed participation as a means of raising long-standing Primary Health Care challenges, including distance, inadequate maternity space, poor water and sanitation, limited staff accommodation and facility congestion. They also perceived participation as strengthening local ownership and supporting the sustainability of approved investments.

Conversely, participants from the health sector noted that community-identified projects were not always informed by technical assessments of service-delivery bottlenecks. Projects were more likely to address actual needs and align with district health priorities when District Health Office staff, facility staff, local authorities and community structures worked together. Where coordination was weak, a completed project could still lack equipment, staff, medicines, utilities or maintenance arrangements.

"The community can tell us what they need, but sometimes the prioritisation process moves faster than the technical assessment. As a result, some health facilities have been constructed in unsuitable places that do not meet our criteria."

— DHO officer, IDI-8

District Health Office participants supported community involvement but called for stronger technical appraisal, while Local Authority officials emphasised procedural and accountability requirements. Community representatives described limited feedback after submitting requests as a persistent bottleneck. They were not always informed how submissions had been reviewed, prioritised or acted upon, leaving them with the impression that their priorities were not valued.

"We are asked to submit our priorities in the community, but after submitting them we do not always hear what happened. People start thinking their views were ignored, even when maybe the project was still being processed."

— Community representative, IDI-14

Community and health-facility participants described their involvement as uneven across the different stages of health-related project cycles. Community representatives reported that, although they were consulted when needs were identified, their involvement declined during technical review, procurement, implementation monitoring and post-completion assessment. Facility staff similarly reported that consultation sometimes occurred only after decisions had been made, limiting their ability to advise on infrastructure layout, equipment requirements, water sources, power supply and staffing implications. This reduced the likelihood that completed investments would immediately function as service-delivery assets.

"Sometimes we only see the contractor on site after decisions have already been made. If we, as local health workers are consulted earlier, we can advise on things like water situation, power, patient flow and where the rooms should be placed."

— Health facility staff member, IDI-9

Perceived Factors that Enable or Constrain the Contribution of Constituency Development Fund Investments to Primary Health Care Service Delivery

Stakeholders identified factors that enabled or constrained the contribution of Constituency Development Fund investments to Primary Health Care service delivery. Enabling factors included timely funding, coordination between local authorities and health-sector actors, technical appraisal, community participation, monitoring and alignment with district health priorities. Together, these factors strengthened alignment between investments, service-readiness requirements and accountability processes. Constraints included delayed approvals, procurement bottlenecks, limited technical capacity, weak communication, staffing shortages, medicine gaps, inadequate maintenance, weak feedback loops and poor links between capital projects and recurrent operational support.

Participants noted that local authorities could finance infrastructure through Constituency Development Fund but lacked authority over health human resources, medicine supply or recurrent health financing, which are centrally funded; as a result, some Constituency Development Fund-supported facilities improved physical readiness without guaranteeing functional clinical services.

"The Fund can build structures, but if there are no health workers deployed in time, or no medicines or operating funds available, the community will still complain that services have not improved."

— Local Authority official, KII-2

From the District Health Office perspective, projects prioritised without adequate technical input risked responding to visible community demand while failing to address staffing,

equipment, utilities or referral readiness; one community representative described how Ward Development Committee decisions could bypass Neighbourhood Health Committees and select projects based on political visibility, without asking what the health post needs. Local Authority officials, in turn, presented approval delays as a major bottleneck, while noting that procurement procedures were meant to protect public funds, so delays were not always negligence but were intended to ensure accountability.

Community representatives also noted that preventive and community-based priorities, such as community-based malaria activities, were harder to accommodate within Constituency Development Fund because they were viewed as recurrent rather than capital activities, creating a perceived gap between community health priorities and the kinds of investment Constituency Development Fund typically supports.

A recurring concern was the mismatch between capital works and recurrent service inputs. Participants explained that new or rehabilitated health facilities funded through the Constituency Development Fund still required health workers, medicines, equipment, waste-management arrangements, electricity or solar systems, water points, transport support and maintenance budgets to operate effectively. When these recurrent inputs were delayed or absent, communities sometimes perceived that the Constituency Development Fund had failed, even when the local authority had completed the approved infrastructure component. This finding shows why project success should extend beyond construction completion and why Constituency Development Fund monitoring should include functionality indicators.

"A building on its own does not treat patients. If there is no nurse, no drugs, no water or no equipment, then people will still travel elsewhere even when the structure is there."

— DHO officer, IDI-11

Stakeholder Recommendations

Stakeholders recommended that proposed Constituency Development Fund health infrastructure projects include a clear facility-readiness justification, DHO technical review, links to district health plans and evidence of community consultation. They also called for better feedback to communities after project submissions, stronger implementation monitoring, and practical indicators for assessing whether completed projects improve access, readiness, referral capacity, water and sanitation, staffing, medicine availability, equipment functionality and community satisfaction. Participants saw stronger coordination between Local Authorities, District Health Offices, health facilities and community structures as necessary to ensure that Constituency Development Fund investments respond to both visible community priorities and less visible service-delivery gaps.

"If the District Health Office and the local authority sit together before approval, it becomes easier to know whether a proposed project will really support services or whether another facility need is more urgent."

— DHO officer, IDI-12

Across the four objectives, stakeholders understood Constituency Development Fund investments as useful but conditional contributors to Primary Health Care. The strongest perceived contributions were health facility infrastructure, staff accommodation, maternity space, water and sanitation, roads, ambulances, solar power and equipment. Participation created opportunities for engagement, but limited feedback, weak coordination and gaps between community preferences and technical appraisal reduced

effectiveness. Constituency Development Fund's contribution to functional Primary Health Care depended on whether capital investments were linked to other health-system inputs, reinforcing the study's central argument that Constituency Development Fund is an enabling financing pathway, not a complete Primary Health Care intervention.

Stakeholders further suggested that Constituency Development Fund-supported Primary Health Care projects should include a simple pre-approval checklist and a post-completion functionality review. The pre-approval checklist would confirm whether the proposed project addresses an identified district health priority, whether technical officers have reviewed the site and design, and whether recurrent requirements have been discussed with the responsible health authorities. The post-completion review would assess whether the investment is in use, whether it has the necessary staff, medicines, utilities and equipment, and whether communities have received feedback on its status and expected benefits.

> *"When a project is completed, there should be a visit to check whether it is helping services. Completion should not just mean the building is handed over; it should mean the facility can use it."*
>
> — Local Authority official, KII-4

Discussion

The findings indicate that stakeholders in Lufwanyama District viewed Constituency Development Fund investments as useful but conditional contributors to Primary Health Care service delivery, rather than as a direct source of clinical services. Investments in facility construction, rehabilitation, maternity spaces, water and sanitation, staff accommodation, solar power, roads and ambulances were valued because they addressed practical barriers to access, readiness, referrals and day-to-day service continuity. This aligns with health systems strengthening literature, which shows that financing improves service delivery when it is translated into connected system inputs rather than isolated capital projects [2, 9].

In Lufwanyama, Constituency Development Fund-supported infrastructure became meaningful when it improved facility usability, staff availability, referral movement, cold-chain support and patient access. This supports the view that financing contributes to Primary Health Care through its interaction with workforce, medicines, technologies, service organisation and operational support, not through construction alone. The findings on roads, ambulances and medicine distribution also point to an indirect pathway: stakeholders experienced these investments as referral-system inputs that helped emergency movement, maternal referrals and commodity distribution. This interpretation is consistent with evidence on rural Primary Health Care access, referral systems and community-based referral and follow-up in Zambia [3–5], although these qualitative findings should not be read as measured clinical outcomes.

These findings suggest that Constituency Development Fund should be treated as a catalytic input within the local health system, not as an independent community programme. Its contribution lies in removing specific bottlenecks that prevent Primary Health Care facilities from functioning well, especially in rural settings where geographic isolation and infrastructure gaps are closely connected to access. Constituency Development Fund can strengthen the "hardware" of Primary Health Care, such as buildings, staff houses, water points, transport assets and energy systems.

Evidence on water, sanitation, hygiene, waste-management and electricity services in health facilities reinforces the importance of these inputs for safe and quality care [10, 11]. However, these investments depend on complementary "software" functions, including planning, supervision, maintenance, staff deployment, supply-chain responsiveness and community trust. Without these functions, an

investment may be visible and politically appreciated but only partly useful for service delivery. This distinction helps explain why stakeholders valued Constituency Development Fund while still worrying that completed projects sometimes remained underused or produced fewer benefits than expected.

The findings on participation, technical appraisal and governance show that Constituency Development Fund created local decision space for communities and local authorities to identify health priorities, but this was most effective when combined with DHO technical appraisal and facility-level evidence. This aligns with Bossert's decision-space perspective and later work by Bossert and Mitchell, which argue that decentralisation improves responsiveness only when local authority is matched by institutional capacity and accountability [12, 13].

The findings also relate to Abimbola et al.'s emphasis on the role of local context in shaping decentralised reforms [14], which is evident in Lufwanyama, where rural distance, staffing and referral constraints shaped how Constituency Development Fund investments were experienced. Community participation alone did not guarantee improved service delivery when project selection was not linked to technical review, implementation capacity and feedback mechanisms. This finding is consistent with social-accountability literature showing that community structures strengthen responsiveness only when formally linked to planning, answerability and communication systems [17-20].

The study also shows that local participation means more than asking communities to submit project requests. Meaningful participation requires a continuous loop: communities identify needs, technical actors assess feasibility and service relevance, local authorities communicate decisions, and communities receive feedback on implementation progress and functionality after completion. When this loop is incomplete, participation can feel one-sided. Communities provide information about their needs but may not receive a clear explanation of how those needs are ranked, funded or deferred. In Lufwanyama, this weakened the accountability value of Constituency Development Fund because communities were more likely to see the Fund as responsive only when projects were approved, rather than understanding the technical, budgetary and procedural reasons why some priorities could not be funded immediately.

Stakeholders identified coordination, technical appraisal, monitoring, alignment with district health priorities and recurrent health-system support as factors that enabled Constituency Development Fund investments to contribute to Primary Health Care service delivery. These factors aligned investments with service-readiness requirements and accountability processes. Approval delays, procurement bottlenecks, weak technical input, staffing shortages and medicine gaps constrained that contribution. These findings are consistent with health-systems-strengthening literature, which emphasises interactions among financing, workforce, medicines, information systems, governance and service organisation [9], and with regional evidence from Sub-Saharan Africa showing mixed decentralisation outcomes where resource transfer, implementation capacity and accountability systems remain incomplete [15, 16].

Lufwanyama's experience reflects this pattern: Constituency Development Fund improved visible service-enabling conditions, but its effect on Primary Health Care remained conditional on health workers, medicines, referral arrangements and recurrent financing that fall outside local authority control. The findings also align with Zambia-specific literature: Chama and Sichone and Dar show that decentralised health service delivery in Zambia has been limited by weak participation,

incomplete devolution and constrained local capacity [23, 24], while Casey et al. and Chambaka and Mutono-Mwanza identify planning, monitoring, transparency and implementation bottlenecks in Constituency Development Fund processes more broadly [21, 22]. This study extends that literature with Primary Health Care-specific evidence of how such bottlenecks affect facility readiness, referral capacity, maternity services, water and sanitation, staffing and recurrent service support.

These findings further show that rural equity is a practical implementation issue, not only a policy objective. In districts such as Lufwanyama, communities far from referral facilities often experience distance, poor roads, transport delays, staffing shortages and commodity interruptions as overlapping barriers. A Constituency Development Fund-funded road, ambulance, staff house or maternity annex may therefore promote equity when it reduces the disadvantage faced by remote populations. However, this equity effect is weakened when investments are distributed without systematic attention to service coverage gaps, referral catchments, population need, seasonal access problems and facility readiness. If Constituency Development Fund is to advance Primary Health Care equity, project selection should be informed by both community voice and district-level evidence on underserved areas, high-burden catchments and facilities with the greatest readiness constraints.

These findings support the study's stakeholder recommendations: facility-readiness justification, formalised DHO technical review, and stronger feedback and accountability mechanisms follow directly from evidence that Constituency Development Fund works best when community priorities are balanced with health-sector evidence and recurrent support. This is consistent with social accountability literature showing that community voice initiatives can shift expectations from informal favours toward service entitlements [20], and with calls to map the multiple actors and interfaces involved in Primary Health Care co-production and accountability [19]. Methodologically, the qualitative single-case design enabled in-depth interpretation of how four stakeholder categories understood Constituency Development Fund within Lufwanyama's rural service-delivery context, with triangulation across interviews, field notes and documents strengthening this interpretation.

The study's findings also have implications for sustainability. Many Constituency Development Fund-supported health investments are capital-intensive, but their long-term contribution depends on recurrent arrangements that are often outside the Constituency Development Fund approval cycle. A staff house requires maintenance; a maternity annex requires equipment, water, electricity, privacy arrangements and skilled staff; an ambulance requires fuel, drivers, servicing and referral coordination; and solar systems require maintenance and replacement planning. If sustainability is not considered at project appraisal stage, Constituency Development Fund can unintentionally create unfunded obligations for the health sector and local authority. This suggests that sustainability screening should also become part of the approval process for Constituency Development Fund-supported Primary Health Care projects, with explicit attention to who will operate, maintain and finance the asset after completion.

An important implication is that Constituency Development Fund monitoring for health investments should move from an output-based orientation to a functionality-based orientation. Counting the number of health posts, staff houses, maternity annexes or water points completed provides useful accountability information, but it does not show whether Primary Health Care delivery has improved. Functionality-based monitoring would ask whether services are closer to

communities, whether health workers can remain on site, whether pregnant women have safer spaces for delivery, whether referrals move faster, whether facilities have reliable water and power, and whether patients experience improved responsiveness. Such indicators would make Constituency Development Fund reporting more relevant to Primary Health Care outcomes while remaining practical for local authorities and health offices.

At policy level, the findings suggest that Constituency Development Fund does not need to become a health-sector fund to contribute more effectively to Primary Health Care. What is needed is stronger integration between Constituency Development Fund planning and existing district health planning systems. This could include routine participation of DHO technical staff in project appraisal, use of facility-readiness evidence during prioritisation, alignment with Integrated District Plans and district health plans, and joint monitoring after completion. These measures would preserve the community-driven character of Constituency Development Fund while reducing the risk that projects are selected mainly for visibility, political appeal or immediate public demand without enough attention to service-delivery functionality.

Conclusion

Stakeholders in Lufwanyama District viewed Constituency Development Fund investments as important but conditional contributors to Primary Health Care. The investments strengthened service-enabling inputs, including infrastructure, staff accommodation, maternity spaces, water and sanitation, transport, selected technologies and facility readiness. Alignment with district health plans, technical appraisal, coordination, community participation, monitoring, accountability and recurrent health-system support enabled their contribution to service delivery. Delayed implementation, procurement bottlenecks, staffing shortages, medicine gaps, maintenance needs, weak feedback loops and inadequate recurrent financing constrained the translation of completed projects into usable services.

The Constituency Development Fund is best understood as an enabling financing pathway rather than a stand-alone service-delivery mechanism. The study recommends that health-project approvals require alignment with district health plans, documented facility-readiness gaps and recurrent-input commitments; that District Health Office technical review assess workforce, financing, medicines, referral links, utilities, maintenance and sustainability; that local authorities, Constituency Development Fund committees, health facilities and community structures provide clear feedback on project decisions; and that completed investments be monitored using functionality indicators, including access, maternity space, water and sanitation, staffing, referral capacity, equipment, medicines and community satisfaction.

Limitations and Future Research

This qualitative single-case study does not claim statistical generalisability beyond Lufwanyama District, but it offers context-specific evidence and transferable lessons for comparable rural settings. Inclusion of administrative, health-sector, facility and community perspectives, together with triangulation of interviews, field notes and documentary evidence, strengthened contextual credibility. Future quantitative, mixed-methods, comparative and longitudinal studies should assess effects on service utilisation, access, waiting times, referrals, maternal and child health uptake, staffing, medicines, equipment and maintenance, and examine how participation, technical appraisal, procurement, accountability and feedback influence functionality, sustainability and community trust. Longitudinal follow-up is particularly important because benefits may emerge only

after recurrent inputs are secured and facilities have operated for sufficient time.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgements

The authors are grateful to the stakeholders and participants who supported this study and generously shared their time, experiences and perspectives. The authors also acknowledge Texila American University for its academic and institutional support.

Ethical Approval

Ethical clearance was granted by ERES Converge (Ref. 2026-Jul-001), with permission from the Cabinet Office Decentralisation Unit (Ref. DS/2/29/2) and relevant provincial and district authorities. All participants provided written informed consent before interviews. Confidentiality was maintained through participant codes, and no personally identifiable information is reported. Because of confidentiality requirements, the qualitative data are not publicly available but may be obtained from the corresponding author on reasonable request, subject to applicable ethical approvals.

Author Contributions

Mukuka, J.M.: Conceptualisation, Methodology, Investigation, Formal Analysis, Writing – Original Draft. Kooma, E.H.: Supervision, Writing – Review & Editing. Both authors approved the final manuscript.

Data Availability

Qualitative data are not publicly available because of participant confidentiality. De-identified data may be requested from the corresponding author, subject to reasonable request, ethical approval and institutional permission.

Funding

No specific funding was sourced or declared for this study.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research ISSN: 2520-3088

https://doi.org/10.21522/TIJAR.2014.13.04.Art004 Volume 13 Issue 4, 2026

Ergonomic Challenges and their Impact on Student Well-being: A Qualitative Study in a Nigerian University

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Cite this article as: OGBE, Alex, Michael Olabode Tomori, Emelonye Amaka Doris, and Akwilini Catherine. Ergonomic Challenges and their Impact on Student Well-being: A Qualitative Study in a Nigerian University. Texila Int J Acad Res. 2026;13(4).
https://doi.org/10.21522/TIJAR.2014.13.04.Art004

Received: 23.07.2026

Accepted: 25.09.2026

Published: 30.10.2026

Article Type: Original Research

Abstract *Ergonomic challenges within university learning environments are increasingly recognized as important determinants of student health and academic performance. However, most studies in low- and middle-income countries focus on quantitative assessments, with limited attention to students' lived experiences. This study employed a qualitative descriptive design using open-ended responses collected via an online survey administered to 352 undergraduate students at the University of Calabar, Nigeria. Data were analyzed using inductive thematic analysis to explore students' experiences, perceived impacts, and coping mechanisms related to ergonomic challenges in their learning environments. Three major themes emerged: (1) Physical strain and bodily discomfort, characterized by musculoskeletal pain and visual strain due to non-adjustable furniture and poor environmental conditions; (2) Cognitive exhaustion and academic disruption, where discomfort impaired concentration, reduced engagement, and contributed to absenteeism; and (3) Institutional neglect and adaptive coping, highlighting the absence of supportive infrastructure and students' reliance on improvised strategies. These findings demonstrate that poor ergonomic conditions extend beyond physical discomfort to significantly affect mental well-being and academic outcomes. Ergonomic deficiencies in university settings represent a critical but under-addressed public health issue. Interventions should prioritize human-centered classroom design, inclusive infrastructure, and institutional policies that support student well-being.*

Keywords *Ergonomics, Learning Environment, Nigeria, Qualitative research, Student Well-being, University students.*

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Introduction

The built environment of a higher education institution serves as an active, continuous background against which a student's daily academic and physiological life unfolds. Tertiary education places exceptional cognitive and physical demands on students, requiring them to spend long hours interacting with fixed architectural features, rigid lecture theater seats, traditional laboratory benches, and highly unpredictable micro-climatic conditions [1, 2]. Within the field of contemporary educational ergonomics, the physical lecture space is recognized not merely as a container for learning, but as a critical mediator of physiological health, student engagement, and long-term cognitive stamina [3, 4].

However, in many developing nations, institutional infrastructure design and campus furniture procurement frequently bypass user-centered parameters. When these physical structures fail to accommodate the natural body measurements and anthropometric variations of the student population, a profound anthropometric mismatch occurs [5, 6]. This structural misalignment forces students to continuously adopt awkward, non-neutral, and fatiguing postures. The immediate physiological consequence is sustained muscle strain, localized circulatory restriction, and early-onset musculoskeletal disorders (MSDs) that predominantly affect the lumbar region, neck, and shoulders [7]. Over time, what begins as transient physical discomfort during a morning lecture crystallizes into chronic somatic distress, directly undermining a student's capacity for sustained concentration, information processing, and overall academic success [8, 9].

While quantitative research remains indispensable for mapping the statistical prevalence of musculoskeletal pain and documenting macro-level infrastructure failures, it naturally simplifies the rich, multifaceted spectrum of human discomfort into clinical numbers and percentages [10]. Quantitative metrics are inherently limited; they cannot fully capture the visceral reality of chronic somatic pain experienced by a student during a high-stakes, multi-hour examination [11]. They fail to articulate the deep emotional frustration and psychological alienation born from sitting at a desk that actively rejects one's physical dimensions, nor can they measure the profound, cumulative exhaustion that comes from navigating overcrowded, acoustically hostile, and poorly ventilated lecture halls [12, 13].

By reducing systemic ergonomic deficiencies to isolated, sterile data points, traditional empirical approaches risk obscuring the true human cost of poor institutional design. To fully understand these dynamics, researchers must explore the qualitative, subjective experiences of the students themselves [14]. Investigating how individuals personally perceive their physical surroundings, negotiate bodily pain within competitive academic environments, and experience emotional fatigue provides a holistic view of the learning ecosystem [15, 16]. This study addresses this exact imperative, shifting the analytical focus from macro-statistics to the authentic voices, lived realities, and personal frustrations of the student body.

Furthermore, student populations in developing West African socio-economic landscapes face a distinct, compounded layer of infrastructural vulnerabilities. In Nigeria, contemporary public higher education is characterized by a severe structural paradox: an unprecedented explosion in student enrollment that has completely outpaced state funding, regular maintenance cycles, and institutional capital development [17, 18]. Consequently, historic public institutions are forced to stretch pre-existing, frequently outdated infrastructure to accommodate populations several times their original design capacity. This structural deficit manifests as intensely congested lecture theaters, an absence of adjustable or

ergonomically sound learning workstations, compromised indoor air quality, and elevated thermal stress that exacerbates physical discomfort in tropical climates [19, 20].

Faced with these harsh realities, university students are not passive observers; they act as resilient agents who must continuously invent, deploy, and modify spontaneous coping mechanisms simply to navigate their academic schedules [21]. These informal adaptations range from physical workarounds—such as standing for hours along crowded corridors, leaning against hot walls, or sharing highly compressed seating spaces—to psychological suppression of physical pain in pursuit of academic survival [22, 23].

Despite the severity of these conditions, there remains a critical gap in contemporary empirical literature regarding how West African tertiary students qualitatively experience, interpret, and bodily adapt to daily ergonomic stressors [24, 25]. Uncovering these personal perceptions and localized micromanagement strategies is vital for designing empathetic, context-specific institutional policies, targeted infrastructural upgrades, and functional student welfare frameworks [26, 27].

This study directly addresses this gap in the literature. Utilizing qualitative survey data collected via an online platform, this research explores the authentic lived experiences, personal perceptions, structural frustrations, and spontaneous coping mechanisms of students at the University of Calabar, Nigeria, as they navigate and resist systemic ergonomic challenges.

Methods and Study Design

Study Design

This study adopted a qualitative descriptive design to explore students' experiences and perceptions of ergonomic challenges within university learning environments [28]. The qualitative descriptive approach was selected because it enabled the researchers to obtain direct and relatively unembellished descriptions of students' experiences, perceived effects of ergonomic conditions, and coping strategies in their own words. The study was qualitative in design and analysis. Although the online survey also contained structured demographic questions, these items were used only to characterize the participants and provide contextual information for interpreting the qualitative findings; they did not constitute a separate quantitative component and were not subjected to inferential statistical analysis.

Participant Recruitment, Sampling Strategy, and Response Rate

The recruitment of participants for this qualitative descriptive study was conducted between April and June 2026. A non-probability convenience sampling technique, supplemented by snowball sampling, was employed to recruit undergraduate students from the University of Calabar, Nigeria. Initial recruitment messages containing the study description, data privacy assurance, and an electronic link to the Google Forms survey were distributed across official and departmental student WhatsApp groups, campus mailing lists, and social media platforms commonly utilized by the student body. To enhance the reach and diversity of the sample across various faculties, respondents were actively encouraged to share the survey link with their peers (snowball sampling). Out of approximately 380 initially targeted students, a total of 352 valid responses were successfully received. These 352 valid responses constituted the qualitative survey dataset used for analysis, while the structured demographic items were used only to characterize the study participants.

Inclusion and Exclusion Criteria

To ensure the integrity and relevance of the data collected, strict inclusion and exclusion criteria were applied:

- **Inclusion Criteria:** Registered full-time undergraduate students of the University of Calabar across all academic years (first to sixth year) who had access to the online survey platform and voluntarily provided informed consent were included.
- **Exclusion Criteria:** Part-time students, weekend program students, sandwich students, university staff members, and students who were concurrently employed full-time were excluded from the study. These groups were excluded because their daily campus routines, lecture schedules, and environmental exposures differ substantially from those of full-time undergraduate students.

Demographic Characteristics

A total of 352 students participated in the study. The demographic profile of the respondents revealed a balanced gender distribution comprising 185 males (52.56%) and 167 females (47.44%). The majority of the participants (89.49%, n = 315) fell within the 21–25 age bracket, with an overall mean age of 23 years. Regarding academic progression, representation spanned across all levels, with third-year students constituting the highest proportion (48.01%, n = 169). In terms of residential status, 71.88% (n = 253) resided in off-campus private hostels, 23.01% (n = 81) lived in school hostels, and 5.11% (n = 18) lived at home. Furthermore, 98.01% (n = 348) reported having no pre-existing physical disabilities, while 1.99% (n = 7) reported living with a disability.

These demographic data were used descriptively to provide contextual information about the participants and were not treated as a separate quantitative analytical component.

Survey Development and Piloting

The data collection instrument was a self-structured, multi-sectional questionnaire developed following an extensive review of existing literature on educational ergonomics, the Modified Nordic Musculoskeletal Questionnaire (NMQ), and literature concerning cognitive and physical well-being. The instrument contained structured demographic questions and open-ended questions designed to elicit detailed descriptions of students' experiences of classroom infrastructure, physical discomfort, perceived academic impacts, and coping strategies.

Prior to full-scale deployment, the questionnaire was pilot-tested using a convenience sample of 30 undergraduate students from a neighboring tertiary institution (Cross River University of Technology) who shared similar demographic and infrastructural characteristics with the target population. The pilot exercise focused on assessing the clarity, readability, relevance, comprehensibility, sequencing, and approximate completion time of the survey questions. Feedback from the pilot participants was used to refine ambiguous wording and improve the clarity and organization of the instrument before the final online survey was administered. The pilot responses were not included in the final qualitative dataset.

Qualitative Data Collection and Data Saturation

Qualitative data were collected through open-ended, free-text questions embedded within the online survey. These questions invited students to provide narrative descriptions of their experiences regarding classroom furniture mismatch, visual strain, environmental discomfort, perceived effects on learning, coping strategies, and psychological frustrations. The open-ended responses constituted the primary qualitative dataset for the study.

Because the survey was administered online and responses were submitted asynchronously, saturation was assessed iteratively rather than on the basis of a predetermined numerical threshold. During data collection and

preliminary analysis, successive groups of responses were reviewed and compared with previously identified codes and developing categories. The researchers monitored whether incoming responses generated substantively new codes, concepts, properties, or thematic dimensions relevant to the study objectives. Particular attention was given to whether later responses added new information to the developing thematic structure or primarily reinforced concepts that had already been identified.

Thematic saturation was considered to have been reached when successive responses no longer contributed substantively new codes, concepts, or thematic dimensions and instead provided further examples, elaborations, or variations of concepts already represented in the developing coding framework. The final qualitative dataset comprised 352 valid responses. Thus, saturation was treated as an analytical judgment based on the informational content and recurrence of concepts within the responses rather than simply as a function of the number of completed questionnaires.

Researcher Positionality and Reflexivity

As an academic researcher and clinical anatomy lecturer, the principal investigator maintained active reflexivity throughout the research process. Recognizing that personal familiarity with university structural deficits could potentially introduce interpretive bias during qualitative coding, the researcher maintained a reflexive journal. This practice documented preconceptions regarding institutional neglect and ensured that the thematic analysis remained grounded strictly in the authentic voices and lived experiences of the student participants rather than preconceived notions.

Coding Procedures and Number of Coders

Qualitative textual data extracted from the open-ended survey responses were exported into NVivo software for systematic thematic analysis following Braun and Clarke's reflexive thematic analysis framework. To ensure analytical rigor and minimize individual subjectivity, coding was independently performed by two trained qualitative coders (the principal investigator and an independent research assistant). The two coders initially reviewed a subset of transcripts to generate an initial codebook, independently coded the entire dataset, and subsequently met to compare codes, resolve discrepancies through consensus, and finalize the core overarching themes and sub-themes.

Methods Used to Establish Credibility and Trustworthiness

To establish trustworthiness and methodological rigor, the study adhered to Lincoln and Guba's evaluative criteria for qualitative research:

1. Credibility: Credibility was achieved through investigator triangulation, where two independent coders analyzed the qualitative dataset, and through member checking with a small subset of student representatives who confirmed that the synthesized themes accurately reflected their lived realities.
2. Transferability: Thick, detailed descriptions of the study setting, participant demographics, and contextual infrastructural challenges at the University of Calabar were provided to enable other researchers to assess the applicability of findings to similar low- and middle-income educational settings.
3. Dependability: An explicit, transparent audit trail documenting every stage of data collection, coding decisions, and thematic development was maintained throughout the research process.
4. Confirmability: Analytical neutrality was maintained by ensuring that all research findings, themes, and interpretations were

directly supported by verbatim participant quotations rather than researcher assumptions.

Selection of Quotations

Verbatim quotations included in the results chapter were selected using a purposive selection strategy. Quotations were chosen based on their vividness, conceptual clarity, and capacity to powerfully encapsulate the core essence of each identified theme or sub-theme. Care was taken to select representative statements from a diverse range of participants across different genders and academic levels while ensuring complete participant anonymity.

Data Collection

The survey included structured demographic questions and open-ended items that invited participants to describe their experiences with classroom infrastructure, physical discomfort, academic impacts, and coping strategies. The demographic questions were used only to provide contextual information about the participants, whereas the open-ended responses constituted the primary qualitative dataset for analysis. Participation was voluntary and anonymous.

Data Analysis

Qualitative data from the open-ended responses were analyzed using inductive thematic analysis following the approach described by Braun and Clarke [29]. Responses were read repeatedly to ensure familiarity, coded systematically, and grouped into themes and sub-themes. The analysis focused on identifying recurring patterns related to ergonomic challenges and their perceived impacts. No inferential statistical analysis was conducted because the study was designed as a qualitative descriptive inquiry.

Results

The thematic analysis of the open-ended text dataset revealed three primary themes that define the ergonomic realities of the student body at the University of Calabar.

Theme 1: Physical Strain and Systematic Bodily Discomfort

The first theme captures the direct physiological toll of the university's built environment. Students described their day-to-day existence as a constant struggle against physical exhaustion, with non-adjustable furniture and poor environmental controls causing widespread pain.

Sub-theme 1: Spinal and Musculoskeletal Fatigue

Students detailed how sitting on long, metallic benches for consecutive multi-hour lectures forces them into constant slouching. This awkward posture triggers intense pain in the lower back, neck, and shoulders.

> *"By the second hour of sitting on those flat wooden benches, my entire lower back goes numb, and a sharp pain shoots up to my shoulders. You can't lean back, you can't adjust the seat, you just have to endure the stiffness."*

Sub-theme 2: Ocular Strain and Thermal Discomfort

Beyond bad chairs, the lack of sun control—for example, the absence of window blinds in some lecture halls—allows harsh tropical light into lecture halls, making it incredibly difficult to see screens or whiteboards. This glare causes chronic headaches and severe eye strain.

> *"The sun pours directly into the lecture hall because there are no blinds. You are constantly squinting to see the notes, and within an hour, a splitting headache sets in. Combined with the heat, it makes the room feel unbearable."*

Theme 2: Cognitive Exhaustion and Academic Deterioration

The second theme highlights how physical discomfort directly compromises students' mental performance and academic focus.

Rather than focusing on course material, students find their attention consumed by managing pain.

Sub-theme 1: Attentional Depletion and Classroom Fatigue

Students reported that trying to balance on uncomfortable furniture rapidly drains their concentration, forcing them to mentally disengage from the lecture.

"I want to focus on what the lecturer is saying, but my body hurts so much that I end up just shifting around trying to find comfort. My brain stops processing the information because it's completely focused on the pain."

Sub-theme 2: Absenteeism and Disengagement

Chronic physical fatigue from poorly designed classrooms leads directly to regular absenteeism, with students choosing to stay in their rooms rather than face the physical strain of certain lecture halls.

"There are specific classrooms I completely avoid because I know how painful my body will feel afterward. Missing lectures hurts my grades, but going there feels like a punishment for my health."

Theme 3: Institutional Neglect and Adaptive Resourcefulness

The final theme explores the total absence of university support or specialized accommodations, forcing students to navigate these infrastructural gaps entirely on their own.

Sub-theme 1: Marginalization of Unique Profiles

Students with physical disabilities or unique body types highlighted a complete lack of adaptive or customized seating, leaving them feeling excluded by the campus infrastructure.

"The university designs classrooms as if every student has the exact same body. If you are exceptionally tall, have a physical challenge, or need back support, there is nothing for you. You are completely on your own."

Sub-theme 2: Improvised Coping Mechanisms

To survive the academic calendar, students resort to creative, personal modifications, such as building makeshift stands to keep their laptops at eye level.

"Many of us carry textbooks on flat desks to raise our laptops so we don't ruin our necks."

Discussion

This qualitative inquiry provides a vital, human-centered baseline for understanding how physical spaces directly shape the daily realities of student life, adding necessary depth to prior quantitative metrics of classroom ergonomics [1, 18]. The vivid student descriptions of cervical, lumbar, and ocular fatigue highlighted throughout this study expose the systemic nature of institutional infrastructural failures. When a university provides rigid, unyielding furniture that lacks options for individual physical adjustment, it places an exhausting physical burden directly onto the student body [19, 20].

Crucially, the empirical evidence demonstrates a clear connection between physical space and cognitive capacity, supporting the core tenets of Cognitive Load Theory [30]. In an ergonomically sound environment, a student's cognitive energy is entirely available for learning, synthesizing, and retaining complex academic content. However, when a classroom induces constant physical discomfort, the brain must dedicate continuous attentional and neurological resources simply to manage pain and environmental stressors [31]. This background cognitive load depletes working memory, causing rapid mental exhaustion, disengagement, and increased absenteeism, which ultimately damages academic productivity and performance.

Finally, these findings expose a critical equity issue within public higher education. The lack of adaptive furniture effectively marginalizes students with diverse body types or physical challenges, forcing them to rely on improvised personal fixes to survive lectures [19]. This absence of supportive infrastructure, coupled with a total lack of formal institutional training on ergonomic safety, leaves students highly vulnerable to preventable, long-term musculoskeletal injuries [2].

From a public health perspective, the intersection of musculoskeletal disorders (MSDs), mental fatigue, and compromised academic productivity represents a hidden institutional epidemic. Public health frameworks have historically focused on infectious diseases or lifestyle-related chronic conditions, often ignoring the micro-environmental hazards embedded within educational institutions. However, physical discomfort is not an isolated academic inconvenience; it is a systemic upstream determinant of long-term population health.

When young adults spend years subjecting their bodies to chronic mechanical stress and poor seating postures, it sets a trajectory for early-onset physical degeneration. Furthermore, the persistent cognitive load required to suppress chronic bodily pain induces neurological exhaustion, driving elevated anxiety, sleep disturbances, and systemic mental fatigue. When physical pain causes absenteeism or reduced learning efficiency, it directly undermines student productivity. In public health terms, this creates a damaging cycle where environmental infrastructure deficits diminish human capital, reducing the socioeconomic mobility that higher education is meant to provide.

While ergonomic structural safety is a universal concern, its reality is deeply split between high-income countries and Low- and Middle-Income Countries (LMICs). In high-income contexts, university modernization projects increasingly treat ergonomic integration and smart, adjustable furniture designs as standard procurement benchmarks.

Conversely, tertiary institutions in LMICs—particularly public universities in West Africa—operate under severe funding constraints. In these environments, explosive student enrollment growth has completely outpaced state funding and capital development allocations [17, 18]. Consequently, public institutions like the University of Calabar are forced to stretch aging, rigid, and overcrowded lecture hall frameworks far beyond their original design capacities. In an LMIC setting, the lack of adjustable chairs, poor room ventilation, and intense thermal stress compound the physical toll on the learning body. This turns classroom ergonomics from a matter of optimal comfort into a pressing health equity crisis.

To mitigate these systemic risks, higher education networks must transition from a culture of emergency maintenance to proactive, health-centered structural policies:

1. **Infrastructural Investment Guidelines:** University governing councils and state funding bodies must establish minimum ergonomic specifications for all future classroom procurement. Height-adjustable desks, supportive lumbar seating, and dynamic furniture solutions must be treated as essential institutional capital requirements, rather than luxury upgrades.
2. **National Education Policy Integration:** Ministries of Education should embed physical and environmental health standards directly into the institutional accreditation criteria managed by commissions like the National Universities Commission (NUC). Academic quality assurance frameworks must recognize that student learning capacity is structurally linked to ergonomic safety.
3. **Targeted Student Health Services:** Campus medical clinics must expand their scope beyond reactive primary care to

include proactive ergonomic advocacy. University health services should implement campus-wide ergonomic literacy campaigns, screen incoming students for early-onset musculoskeletal vulnerabilities, and establish clear reporting mechanisms for physical workspace deficiencies.

Conclusion and Recommendations

This study highlights that ergonomic inadequacies in university learning environments are not merely sources of physical discomfort but constitute significant barriers to student health, well-being, and academic performance. The findings demonstrate that poorly designed classroom infrastructure contributes to musculoskeletal strain, cognitive fatigue, and reduced academic engagement, while also disproportionately affecting students with diverse physical needs.

These results position ergonomic conditions as an important but under-recognized public health concern within higher education in low- and middle-income settings. Addressing these challenges requires a shift toward human-centered and inclusive classroom design, alongside institutional policies that prioritize student well-being.

Future interventions should integrate ergonomic standards into infrastructure planning, promote awareness of safe learning practices, and ensure equitable access to supportive learning environments. Improving the physical learning context is essential not only for enhancing academic outcomes but also for safeguarding the long-term health of students.

Strengths and Limitations

This study provides rich qualitative insights from a relatively large and diverse sample of university students, enhancing the breadth of perspectives captured. However, the use of an online survey limited the depth of individual responses compared to in-depth interviews. Additionally, the study was conducted in a single institution, which may limit generalizability to other settings.

Because the study used convenience and snowball recruitment through an online survey, the participants may not fully represent the experiences of all University of Calabar students. Furthermore, although 352 valid responses provided a broad range of qualitative accounts, the asynchronous nature of online free-text responses may have limited the depth and opportunity for probing that would ordinarily be possible in individual interviews or focus groups. The qualitative findings should therefore be interpreted as context-specific descriptions of students' reported experiences rather than as statistically generalizable estimates.

Conflict of Interest

The authors declare no conflict of interest related to this study.

Acknowledgement

The authors extend their sincere gratitude to the students at the University of Calabar for their cooperation and participation in this research project.

Authors' Contributions

- **Ogbe Alex (PhD Candidate):** Conceptualization, methodology, principal investigator, formal analysis, writing original manuscript, and funder of the study.
- **Dr. Michael Olabode Tomori (PhD):** Lead Supervisor of the study, local guide, methodology, investigation guide, writing—review and editing.
- **Emelonye Amaka Doris:** Online data manager, screening of online data, data coding, script typing and editing.
- **Dr. Catherine Akwilini:** Independent reviewer and critiquing of the study from start to finish.

Ethical Approval

Ethical clearance was obtained from the Research and Ethics Committee of Joseph Ayo Babalola University (Approval No: JABU/RGMO/REC/26/021). Before proceeding with online data collection for this study, informed consent was embedded in the online Google Form for willing participants to fill prior to completing the survey. On the online forms, there was no provision for participants' names or initials. It was clearly stated that participation was free and voluntary; hence, participants were free to withdraw from the study at any time without any consequences.

Data Availability

The dataset from which this aspect of the study was taken and analyzed is available from the corresponding author upon reasonable request, subject to ethical approval and institutional data-sharing policies.

Funding

This research was self-funded and was an excerpt from the principal author's PhD thesis at Texila American University. The thesis was titled: *Exploring the Ergonomic challenges and their impact on students Well-being and learning: A case study of University of Calabar, Nigeria.*

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art005

ISSN: 2520-3088
Volume 13 Issue 4, 2026

An Equity-Focused Approach to Health Services and Its Influence on Health-Seeking Behaviour Patterns in Peri-urban Communities: A Study of Matero, Lusaka, Zambia

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Cite this article as: Flint Kenna Zulu, Lazarous Mbulo. An Equity-Focused Approach to Health Services and Its Influence on Health-seeking Behaviour Patterns in Peri-urban Communities: A Study of Matero, Lusaka, Zambia. Texila Int J Acad Res. 2026;13(4).
https://doi.org/10.21522/TIJAR.2014.13.04.Art005

Received: 17.06.2026
Accepted: 18.08.2026
Published: 30.10.2026

Article Type: Original Research

Abstract *Health equity remains a central concern in achieving universal health coverage in Zambia. Despite reforms such as the abolition of user fees and the introduction of the National Health Insurance Management Authority (NHIMA), disparities in healthcare access and utilisation persist. This study examined the influence of an equity-focused approach to health services on health-seeking behaviour among residents of Matero Township in Lusaka, Zambia. A cross-sectional comparative design using mixed methods was employed, involving 252 respondents from public and private health facilities. Findings revealed that while 58.3% of respondents reported access to healthcare services, 41.7% still lacked access, indicating persistent inequities. Systemic barriers were reported by 65.5% of participants, while 57.4% perceived inequalities in service delivery. Key determinants of health-seeking behaviour included distance to health facilities (25.6%), availability of medication (23.3%), and cost of services (22.0%). Although 70.4% expressed confidence in local health services, utilisation remained irregular. The study concludes that while equity-focused reforms have improved access, structural barriers continue to limit optimal utilisation.*

Keywords *Health Equity, Health-Seeking Behaviour, Healthcare Utilization, NHIMA, Peri-urban Health, Zambia.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art005

Introduction

Health-seeking behaviour plays an important role in determining health outcomes and the utilisation of available healthcare services. In Zambia, health sector reforms have aimed at enhancing equitable access through initiatives such as the removal of user fees and the establishment of the National Health Insurance Management Authority (NHIMA) [1, 2]. These reforms were intended to address inequities and improve healthcare delivery across populations.

Despite these efforts, disparities remain evident, particularly in peri-urban settings such as Matero Township. These disparities are influenced by socio-economic differences, system inefficiencies, and accessibility challenges. Understanding how equity-focused approaches influence health-seeking behaviour is critical for improving health outcomes and system performance [3, 4].

Background

Zambia is a landlocked country in Southern Africa with a population of about 21 million people and abundant natural resources. It is divided into ten provinces and 116 districts, with a largely rural population, which creates challenges in accessing healthcare due to long distances to health facilities [2].

Since gaining independence in 1964, Zambia has maintained political stability and introduced major health sector reforms in the early 1990s aimed at improving equity, access, and quality of healthcare. These reforms included decentralization, community participation, and financing changes such as user fees, later partially removed, and partnerships with donors and private providers [1, 2].

Despite progress, healthcare equity remains a challenge due to reduced donor support, socio-economic inequalities, and geographic disparities. Factors such as poverty, education, and location continue to influence access to healthcare services [5]. While public facilities serve the majority and policies like free primary healthcare and national health insurance aim to improve access, barriers such as cost, infrastructure limitations, and cultural beliefs persist [1].

Matero Township reflects these broader challenges, with high population density and mixed use of public and private healthcare. Health-seeking behaviour in this area is influenced by service quality, availability of medicines, waiting times, and provider attitudes, highlighting the need for continued efforts to improve equitable healthcare delivery [2, 5].

Statement of the Problem

The literature shows that healthcare access and health-seeking behaviour (HSB) are influenced by multiple interconnected factors, including socio-economic status, education, geographic location, and systemic health system constraints [5]. Individuals in high-density and low-income areas often face overcrowded facilities, limited resources, and significant financial barriers, which hinder access to care.

Zambia has made significant steps towards improving the health of the population, including the introduction of a national health insurance scheme. However, health inequalities continue to persist, and many people do not have the same opportunities to attain optimal health [1].

Health system challenges such as long waiting times, inadequate staffing, and unequal distribution of resources further contribute to disparities in healthcare utilization. In addition, patients' perceptions of service quality, as well as cultural beliefs and norms, strongly shape decisions about when and where to seek care [3, 5].

The review draws on both theoretical models and empirical evidence, particularly from sub-Saharan Africa, due to similarities in health system contexts. It highlights the importance of social determinants of health such as living

conditions, income, and policy environments in shaping health outcomes and reinforcing inequities [7]. Concepts such as the inverse care law demonstrate that populations with the greatest health needs often have the least access to services [7].

Two major approaches to understanding HSB are discussed:

1. **Pathways Models,** which describe the stages individuals go through when seeking care [8].
2. **Determinants Models**, such as Andersen's model, which explain how predisposing, enabling, and need factors influence healthcare utilization [9].

However, these models have limitations in African contexts, where healthcare systems are pluralistic and individuals often use a mix of public, private, and traditional providers.

Study Objectives

General Objective

To examine the influence of an equity-focused approach to health services on health-seeking behaviour in Matero Township.

Specific Objectives

1. To assess access to healthcare services among residents.
2. To identify barriers affecting healthcare utilization.
3. To determine factors influencing health-seeking behaviour.
4. To evaluate perceptions of equity in healthcare delivery.

Literature Review

The literature shows that healthcare access and health-seeking behaviour (HSB) are influenced by multiple interconnected factors, including socio-economic status, education, geographic location, and systemic health system constraints [5, 11, 12]. Individuals in high-density and low-income areas often face overcrowded facilities, limited resources, and significant financial barriers, which hinder access to care.

Zambia has made significant progress in improving population health through reforms such as the introduction of a national health insurance scheme. However, health inequalities continue to persist, and many people do not have the same opportunities to attain optimal health [1, 21].

Health system challenges such as long waiting times, inadequate staffing, and unequal distribution of resources further contribute to disparities in healthcare utilization. In addition, patients' perceptions of service quality, as well as cultural beliefs and norms, strongly influence decisions about when and where to seek care [13, 15].

The review draws on both theoretical models and empirical evidence, particularly from sub-Saharan Africa, due to similarities in health system contexts. It highlights the importance of social determinants of health such as living conditions, income, and policy environments in shaping health outcomes and reinforcing inequities [6, 7]. The inverse care law suggests that populations with the greatest health needs often have the least access to healthcare services [7].

Two major approaches to understanding HSB are frequently discussed:

1. **Pathways models**, which describe the stages that individuals go through when seeking healthcare services [8].
2. **Determinants models**, such as Andersen's Behavioural Model, which explain how predisposing, enabling, and need factors influence healthcare utilization [9].

However, these models have limitations in African settings where healthcare systems are pluralistic and individuals often utilize a combination of public, private, faith-based, and traditional healthcare providers [16].

Empirical evidence from sub-Saharan Africa shows that healthcare utilization is shaped by cost of care, accessibility, quality of services,

cultural beliefs, and social factors such as stigma [11, 14, 15, 22]. Patients frequently choose providers based on perceived quality and convenience and may delay seeking care because of financial constraints or fear of discrimination [12, 17].

Overall, the literature emphasizes that improving health equity requires addressing not only healthcare services but also broader socio-economic and structural determinants that influence health-seeking behaviour [6, 7].

Concept of Health Equity

Health equity refers to the absence of avoidable or remediable differences in health among populations. Health equity exists when everyone has a fair and just opportunity to attain their optimal health [1]. It emphasizes fairness in access, utilization, and outcomes.

Health-Seeking Behaviour

Health-seeking behaviour (HSB) refers to any action undertaken by individuals who perceive themselves to have a health problem or illness for the purpose of finding an appropriate remedy [3]. HSB is situated within the broader concept of health behaviour, which encompasses activities intended to maintain good health, prevent illness, and respond to health problems when they occur [11, 12].

Factors influencing health-seeking behaviour include:

1. Socio-economic status
2. Cultural beliefs and practices
3. Accessibility of healthcare services
4. Availability of medicines and healthcare personnel
5. Perceived quality of care
6. Health insurance coverage
7. Educational level and health literacy [5, 11, 18, 19].

Andersen's Behavioural Model

The study is guided by Andersen's Behavioural Model, which categorizes determinants into:

1. Predisposing factors (age, gender, education)
2. Enabling factors (income, access, insurance)
3. Need factors (perceived and actual health status)

These factors collectively influence an individual's decision to utilize healthcare services [9].

Equity-Focused Health Reforms in Zambia

Zambia has implemented key reforms through:

1. Abolition of user fees (2006 in rural areas, 2012 in urban areas)
2. Introduction of NHIMA
3. Expansion of primary healthcare services

These reforms were intended to improve access and equity in healthcare utilization [1, 2]. However, disparities persist due to systemic inefficiencies and resource constraints.

Empirical Evidence

Evidence from sub-Saharan Africa indicates that:

1. Distance to healthcare facilities remains a major barrier to service utilization [12, 22].
2. Costs associated with healthcare continue to limit access, despite fee-removal policies [17, 20].
3. Drug shortages undermine confidence in public healthcare facilities [13, 14].
4. National health insurance schemes improve access but may not fully eliminate inequities [18, 19].
5. Informal and traditional healthcare providers remain important sources of care in many communities [16].

These factors continue to shape patterns of health-seeking behaviour across low- and middle-income countries.

Conceptual Framework

The study adopts a framework linking:

1. Equity-Focused Policies → Access to Services → Health-Seeking Behaviour → Health Outcomes
2. Moderating variables include:
3. Socio-economic status
4. Geographical accessibility
5. Healthcare system efficiency

Materials and Methods

Study Design

Mixed methods design was adopted in the study [10]. A cross-sectional comparative study design was used, incorporating both quantitative and qualitative approaches. Data was collected from respondents using structured questionnaires. The sample included individuals from different residential areas, occupations, and demographic groups.

Data analysis was conducted using descriptive statistics, including frequencies and percentages. Variables analyzed included age, gender, marital status, household size, occupation, income, access to healthcare, and perceived barriers.

Study Area

The study was conducted in Matero Township in Lusaka, a peri-urban area characterised by high population density and mixed socio-economic conditions.

Study Population and Sample Size

The study sample consisted of 252 respondents:

- 148 from public health facilities
- 104 from private health facilities
- Participants were aged 18 years and above.

Data Collection Methods

Data were collected using multiple methods to ensure comprehensive and reliable information. A **structured questionnaire** was administered to respondents to gather quantitative data on demographic characteristics, healthcare access, utilization patterns, and perceptions of health services. In addition, **key informant interviews** were conducted with selected healthcare providers and community stakeholders to obtain in-depth qualitative insights into health service delivery and health-seeking behaviour. Furthermore, a **document review** was undertaken to examine relevant policy documents, health reports, and existing literature, providing contextual information and supporting the triangulation of findings from the primary data sources.

Data Analysis

Quantitative data was analysed using SPSS and Microsoft Excel. Descriptive statistics were presented in percentages, tables, and charts. Qualitative data were analysed thematically.

Results

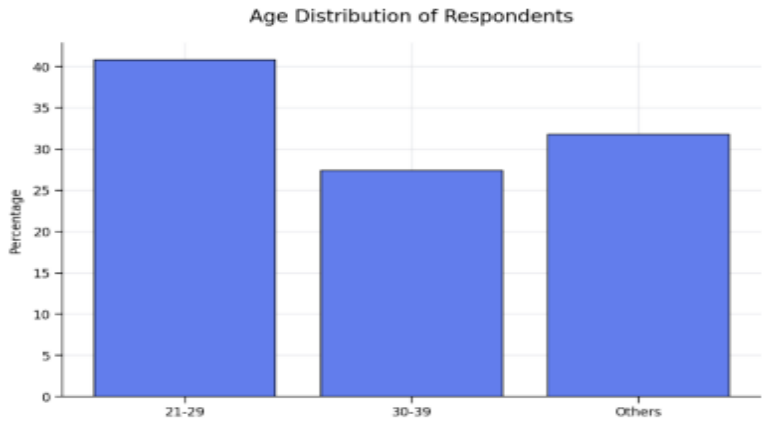


Figure 1. Distribution of Respondents by Age Group

https://doi.org/10.21522/TIJAR.2014.13.04.Art005

The majority of respondents were aged 21–29 years (40.8%), followed by 30–39 years (27.4%), indicating a predominantly young adult population (Figure 1). Most respondents were female, and nearly half were married (49.8%), with a substantial proportion being single (39.9%). All respondents identified as Christian. In terms of residence, most participants lived in high-density areas (49.8%), suggesting potential.

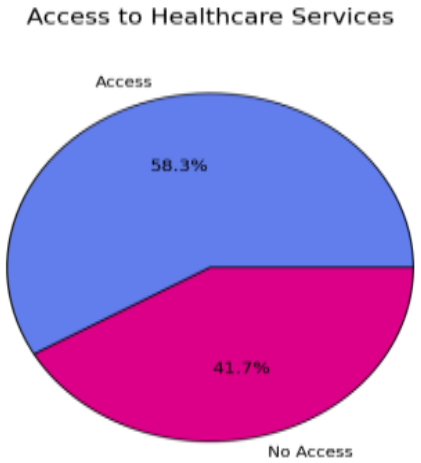


Figure 2. Proportion of Respondents Reporting Access and Lack of Access to Healthcare Services in Matero Township

Pressure on healthcare resources. Household sizes were moderate, with most households comprising 3–5 members. Occupationally, the majority were businesspersons (35.0%) and employed individuals (30.9%), indicating varied income sources. However, income distribution showed variability, suggesting potential financial constraints among respondents.

Access to healthcare services was reported by 58.3% of respondents, while 41.7% lacked access, highlighting a significant service gap (Figure 2). A majority (65.5%) reported systemic barriers, and 57.4% observed inequalities in healthcare services.

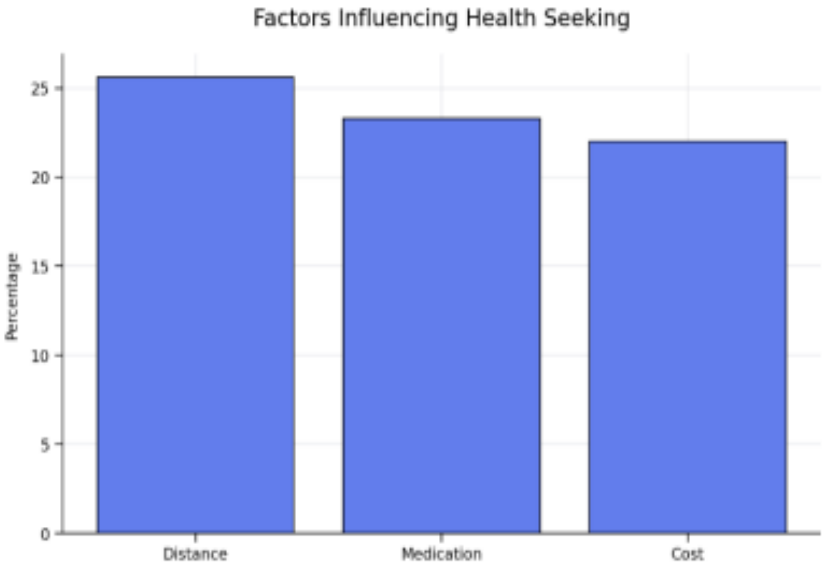


Figure 3. Major Factors Influencing Access to Medical Care

Despite these challenges, 77.6% of respondents reported that healthcare services were culturally appropriate, and 70.4% expressed confidence in local health services.

Healthcare utilization patterns indicated that most respondents visited facilities occasionally (44.8%), while fewer attended regularly (22.4%). Key factors influencing access included distance to healthcare facilities (25.6%), availability of medication (23.3%), and cost of services (22.0%) (Figure 3).

Affordability was a concern, with 60% indicating services were affordable, leaving a significant proportion experiencing financial constraints.

Combined Results Table

Domain	Key Findings	% / Statistics	Statistical Significance	Interpretation
Access & Barriers	Access to healthcare	58.3% Yes/41.7% No	$\chi^2 = 12.84$, $p = 0.0003$	Access strongly linked to systemic barriers
	Systemic barriers	65.5% Yes	Significant	Structural issues limit effective access
	Observed inequalities	57.4% Yes	—	Inequities widely perceived
Utilization Patterns	Occasional visits	44.8%	—	Care mostly non-routine
	Emergency-only visits	23.3%	—	Reactive health-seeking behavior
	Distance barrier	25.6%	—	Main access constraint
	Medication availability	23.3%	—	Supply limitations affect care
	Cost barrier	22.0%	—	Financial constraints persist
Geographic Inequality Perceptions	Residential area vs access	—	$\chi^2 = 9.67$, $p = 0.008$	High-density areas face greater barriers
	Confidence in services	70.4%	—	Trust remains high
	Affordability	60.4%	$\chi^2 = 14.21$, $p = 0.003$	Affordability influences utilization
	Cultural appropriateness	77.6%	—	

Discussion

Findings indicate that while healthcare services are physically accessible in Matero, financial and systemic barriers limit utilization. Cultural practices still influence healthcare choices, particularly among older residents. The results align with existing literature showing that affordability and service quality are key determinants of care-seeking behavior.

These findings suggest that while confidence in healthcare systems exists, structural and systemic barriers continue to limit access and utilization, which directly relates to the study objectives on equity, utilization, and barriers. The study findings demonstrate that equity-focused health reforms in Zambia have improved access to healthcare services but have not fully eliminated disparities. The presence of a substantial proportion of respondents lacking access (41.7%) highlights ongoing inequities consistent with the inverse care law.

Although cultural acceptability and confidence in healthcare services were relatively high, utilisation remained inconsistent, suggesting that access alone does not guarantee use. Persistent systemic barriers such as drug shortages, long waiting times, and cost-related challenges continue to influence health-seeking behaviour.

The study also confirms the relevance of Andersen's Behavioural Model, where utilisation is shaped by enabling factors such as income, accessibility, and service availability. The findings further align with regional studies in sub-Saharan Africa, which show that individuals often navigate multiple healthcare options based on cost, quality, and convenience.

Conclusion

Equity-focused healthcare policies in Zambia have improved access to services in peri-urban areas such as Matero. However, inequities persist due to structural, financial, and systemic barriers. Addressing these challenges is essential for achieving equitable healthcare utilisation. The study concludes that socio-demographic factors and systemic barriers significantly influence access to healthcare services. Although a majority of respondents have some level of access and confidence in health services, gaps remain due to cost, distance, and inequalities.

The findings support the study objectives by demonstrating that inequities, financial constraints, and structural barriers shape health seeking behaviour and service utilization. Efforts should therefore focus on improving service availability, strengthening equity-focused policies, and reducing financial and geographic barriers to achieve equitable healthcare access for all populations.

Recommendations

The Zambia government need to looking into improving medicines supply; strengthen service delivery; expand NHIMA; increase outreach; and reduce cost barriers.

Declaration

The author declares that this study is original and has not been submitted elsewhere. Ethical approval was sought, and informed consent was secured from all participants. No conflict of interest is declared.

Acknowledgements

The author sincerely thanks the residents of Matero Township who participated in this study and generously shared their experiences and perspectives. Special appreciation is extended to the healthcare providers, community leaders, and research assistants who facilitated data collection and provided valuable support throughout the study. The author is also grateful to the supervisor, Dr. Lazarous Mbulo, for his guidance, encouragement, and technical input during the research process. Appreciation is further extended to Texila American University and all individuals who contributed to the successful completion of this study.

Ethical Approval

Ethical principles were strictly observed throughout the study. Permission to conduct the research was obtained from the relevant authorities and participating health facilities. All participants were informed about the purpose of the study, and written informed consent was obtained before participation. Participation was voluntary, and respondents were informed of their right to withdraw from the study at any time without any consequences. Confidentiality and anonymity were maintained by ensuring that no personal identifiers were recorded and that all data were used solely for research purposes.

Author Contributions

Flint Kenna Zulu conceived and designed the study, developed the research instruments, collected and analyzed the data, interpreted the findings, and prepared the manuscript. The supervisor provided academic guidance, methodological support, and critical review of the manuscript. The author read and approved the final version of the manuscript.

Conflict of Interest

The author declares that there are no conflicts of interest regarding the publication of this study. The author has no financial, professional, or personal relationships that could have influenced the conduct, analysis, or reporting of the research.

Data Availability

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. Data are not publicly available to protect the confidentiality and privacy of study participants.

Funding

This study was self-funded by the researcher. No external funding was received from any governmental, non-governmental, commercial, or private organization for the design, data collection, analysis, interpretation, or publication of this research.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art006

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Divergent Trajectories of Universal Health Coverage in Ghana, Kenya, Nigeria, and Tanzania: A Policy Appraisal (2022-2024)

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Cite this article as: Isa Suleiman Abubakar. Divergent Trajectories of Universal Health Coverage in Ghana, Kenya, Nigeria, and Tanzania: A Policy Appraisal (2022-2024). Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art006**

Received: 09.05.2026

Accepted: 31.07.2026

Published: 30.10.2026

Article Type: Original Research

Abstract *This study evaluates the progress toward Universal Health Coverage (UHC) in Ghana, Kenya, Nigeria, and Tanzania using Demographic and Health Survey (DHS) data from 2022–2024. While the global goal is to achieve UHC by 2030, sub-Saharan Africa faces significant structural barriers, including vast informal economies and chronic underfunding of public health infrastructure. Results reveal a concerning divergence in national trajectories: Ghana experienced a significant decline in functional coverage from 62.4% to 5.7% due to the structural failure of its voluntary enrollment model, delayed provider reimbursements, and a subsequent deterioration of public trust. Conversely, Kenya's shift toward mandatory enrollment for the formal sector increased overall population coverage to 34%, although a persistent pro-rich bias remains evident. Meanwhile, Nigeria and Tanzania continue to register low, single-digit functional coverage despite recent ambitious legislative reforms, heavily hindered by extreme poverty and system fragmentation. Multivariate logistic regression confirms that educational attainment and household wealth remain the primary, universal determinants of health insurance status across all four nations. The study concludes that sustainable UHC requires an immediate shift from voluntary, fragmented schemes to unified mandatory systems, supported by robust, automated poverty subsidies and synchronized investments in supply-side health infrastructure.*

Keywords *Demographic and Health Survey, Health Financing, Health Insurance, Policy Appraisal, Sub-Saharan Africa, Universal Health Coverage.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art006

Introduction

The global commitment to achieving Universal Health Coverage (UHC) by the year 2030 represents the foundational cornerstone of Sustainable Development Goal 3 (SDG 3), which aims to ensure healthy lives and promote well-being for all at all ages [1]. This mandate is built upon the moral and economic imperative that all populations, regardless of their socioeconomic standing, geographical location, or employment status, must have unhindered access to necessary health services. These services encompass the full spectrum of essential care, including disease prevention, health promotion, acute treatment, and long-term rehabilitation. Crucially, this access must be provided without subjecting the end-user to debilitating financial hardship. At its core, UHC is fundamentally a matter of equity, human rights, and social justice, requiring national health systems to proactively protect vulnerable individuals from catastrophic health expenditures (CHE) that frequently drive households into cycles of multi-generational poverty [2].

To realize this objective, many developing nations have turned to public health insurance mechanisms as their primary strategic vehicle for health financing reform. These systems theoretically pool financial risk across a broad population base, cross-subsidizing the sick with contributions from the healthy and providing a financial safety net against unpredictable out-of-pocket (OOP) medical costs. However, the path to achieving functional UHC in sub-Saharan Africa is obstructed by a complex landscape of profound socioeconomic inequalities, rapid population growth, and structurally fragmented health systems [3, 4]. In Ghana, Kenya, Nigeria, and Tanzania, entrenched disparities in wealth and formal education create formidable barriers to achieving equitable financial protection.

Historically, health financing in these regions relied heavily on direct OOP payments at the point of care. This model disadvantages marginalized populations, particularly women, children, and the rural poor, forcing them to delay or forgo medical care [5]. Guided by frameworks such as the 2001 Abuja Declaration (where African Union countries pledged to allocate at least 15% of annual budgets to health), legislative reforms have been enacted to move toward prepaid models [6, 7]. Yet, policy implementation frequently collides with material realities: weak public infrastructure, shortages of healthcare professionals, and a vast, undocumented informal economy difficult to capture within traditional payroll-based frameworks [8].

This dynamic environment generates what this paper conceptualizes as the "UHC Policy Paradox." This paradox features an observable divergence in national trajectories despite shared regional goals and macroeconomic pressures. For instance, Ghana, formerly lauded as a regional pioneer in UHC through its National Health Insurance Scheme (NHIS), has recently faced a marked reduction in active, functional coverage [9]. Conversely, Kenya engineered substantial gains through a strategic legislative pivot toward mandatory participation for formal sector employees [10, 11]. Meanwhile, Nigeria and Tanzania register low enrollment levels, indicating that high-level legislative ambitions have yet to overcome grassroots material stagnation [12, 13].

The volatility observed in Ghana's trajectory exposes a vulnerability inherent in voluntary health financing models. When a system relies on voluntary enrollment and annual renewals, stability is linked to continuous service quality and sustained public trust [14]. If perceived utility is compromised—whether by drug stock-outs, administrative inefficiencies, or provider rejections due to delayed state reimbursements—renewal rates decline rapidly. This membership loss confirms a vital lesson: statutory registration success does not equal functional coverage success [15].

This paper provides a comparative inquiry into these four nations. Utilizing Demographic and Health Survey (DHS) data from 2022–2024, this study evaluates respective UHC trajectories, identifies primary socioeconomic determinants driving enrollment, and proposes structural adjustments necessary to accelerate UHC progress.

Materials and Methods

The methodological framework is grounded in a quantitative analysis of standardized Demographic and Health Survey (DHS) datasets. The DHS Program, funded by USAID and administered by ICF International, generates high-quality population and health data. To ensure a contemporary assessment, this study analyzes data extracted from the 2022–2024 survey period across four national samples:

- Ghana (2022): 17,933 households, 15,014 women (aged 15–49), and 7,044 men (aged 15–59).
- Kenya (2022): 37,911 households, 32,156 women (aged 15–49), and 14,453 men (aged 15–54).
- Nigeria (2023–24): 40,047 households, 39,050 women (aged 15–49), and 12,204 men (aged 15–59).
- Tanzania (2022): 15,705 households, 15,254 women (aged 15–49), and 5,763 men (aged 15–49).

These standardized datasets provide a robust benchmark against prior longitudinal studies from the 2013–2015 period.

Statistical Software and Analytical Procedures

All quantitative data cleaning and analyses were conducted using Stata version 17.0 (StataCorp LLC). To account for the complex multi-stage stratified cluster sampling design of the DHS programs, specific survey commands (svy prefix) were applied. Sampling weights were incorporated into all models to adjust for non-proportional geographic allocation and household non-responses, ensuring national representativeness and cross-national comparability.

Multivariate Analysis and Definition of Variables

Multivariate logistic regression was executed to isolate independent predictors of health insurance enrollment, generating adjusted Odds Ratios (aOR) with 95% Confidence Intervals (CI). The primary dependent variable was binary (1 = currently insured by a formal scheme; 0 = uninsured). Predictor variables included:

1. **Educational Attainment:** Categorized as No Formal Education, Primary, Secondary, and Higher (Tertiary) Education.
2. **Wealth Status (Household Wealth Index):** Composite measure based on principal component analysis of asset ownership and housing characteristics, categorized into five quintiles (Poorest, Poorer, Middle, Richer, Richest).
3. **Occupational Status:** Differentiated between professional/clerical/managerial roles and agricultural/informal manual employment.
4. **Demographic and Residential Factors:** Women of reproductive age (15-49), adult populations, and urban/rural residency status.

Results

The quantitative findings from the 2022–2024 DHS datasets reveal a polarized divergence in UHC trajectories across the four nations. While legislative reforms were passed, functional enrollment varies drastically. A high-level overview of these contrasting national pathways is summarized in Table 1.

Ghana: Retention Challenges and Functional Decline

Formerly celebrated as a regional leader in UHC, Ghana experienced a substantial reversal in its health insurance landscape. The 2022

DHS data indicates that active functional coverage among women of reproductive age has decreased to 5.7%, representing a marked reduction from the 62.4% coverage rate recorded in 2014 [10].

While secondary analyses of the 2022 survey indicate high lifetime initial registration (up to 90% reporting past enrollment in the NHIS), the 5.7% metric highlights a structural failure in active membership renewal [10, 17]. This gap confirms a substantial loss of active members driven by a deterioration of public trust and perceived lack of financial protection at points of care. Consequently, the incidence of catastrophic health expenditure in Ghana rose from 1.26% in 2012 to an estimated 11.45% in 2023 [4].

Kenya: Strategic Acceleration and Volume Expansion

In contrast to regional trends of stagnation, Kenya demonstrated verifiable gains through proactive policy interventions. Overall health insurance coverage reached 34% of the national population [16], improving upon 2014 rates of 21.9% for females and 18.2% for males [3].

This success is attributed to state-backed expansion of the National Health Insurance Fund (NHIF) and mandatory formal sector enrollment policies [11]. However, volume growth masks a persistent pro-rich bias: the likelihood of being insured increases directly with household wealth quintiles, leaving poorer demographics underserved [6, 11].

Tanzania: Persistent Single-Digit Stagnation

Despite early community health fund experiments, Tanzania registers critically low coverage levels. The 2022 DHS data shows overall national coverage at 5.7% [16], representing a minor decrease from the 9.1%–9.5% range in 2015. Approximately 94% of women and 93% of men aged 15–49 remain uninsured [16]. Rural residents were found to be 1.3 times more likely to be insured than urban counterparts, reflecting localized community-based health insurance (CBHI) penetration [8].

Nigeria: Regulatory Ambition vs. Implementation Realities

Nigeria's health insurance landscape remains restricted. Preliminary 2023–2024 DHS findings indicate coverage remains stagnant below 10% [16], following historical rates of 1.1% for females and 3.1% for males in 2013 [18].

Although the government passed the National Health Insurance Authority (NHIA) Act of 2022 to mandate coverage [13, 19], the Director-General of the NHIA disclosed in 2024 that fewer than 20 million of over 200 million Nigerians are covered [20]. Multi-dimensional poverty remains a dominant barrier; with roughly 40% living below the poverty line, citizens cannot afford voluntary premiums without extensive state subsidies [21].

Table 1. Comparative Health Insurance Coverage Status (2022-2024)

Country	Recent Coverage Rate (2022-2024 DHS)	Previous Coverage Rate (2013-2015)	Trajectory Assessment
Ghana	5.7% (Women of Reproductive Age)	62.4% (Female coverage, 2014)	Dramatic and concerning drop
Kenya	34% (Overall Population)	18.2%–21.9% (Female/Male, 2014)	Substantial Rise (Significant Improvement)
Tanzania	5.7% (Overall Coverage)	9.1%–9.5% (Female/Male, 2015)	Slight Decrease (Remains Low)
Nigeria	Extremely Limited (Implied <10%)	1.1%–3.1% (Female/Male, 2013)	Limited Improvement (Still Stagnant)

Discussion

The cross-national analysis indicates that legislative mandates alone are insufficient to guarantee UHC; long-term sustainability depends on service quality, macroeconomic stability, and socioeconomic equity.

Deterioration of Public Trust and Functional Failure (Ghana)

Ghana's decline from 62.4% to 5.7% illustrates the structural instability of voluntary models during macroeconomic shocks. Pervasive system failures eroded public trust [5, 17]: public clinics actively reject NHIS cardholders due to severe state reimbursement delays caused by hyperinflation and fiscal deficits between 2022 and 2024 [4] When cards fail to offer financial protection, disenrollment is a rational economic response, triggering a downward spiral of declining risk pools.

The Pro-Rich Equity Gap (Kenya)

Kenya's expansion to 34% demonstrates state capacity for volume growth via mandatory formal sector rules. However, multivariate analysis validates a systemic pro-rich bias: while affluent groups are captured, marginalized households facing out-of-pocket costs remain underserved [11]. Future momentum requires transparent subsidy mechanisms for informal workforce integration.

Mandates Without Operational Capacity (Nigeria and Tanzania)

Nigeria and Tanzania exemplify regulatory ambition colliding with ground realities following the NHIA Act 2022 and UHC Act 2023. With over 90% uninsured in Nigeria and extreme poverty preventing premium payments, alongside supply-side infrastructure shortages [18], legislative mandates remain unenforceable without robust funding allocations like Nigeria's Vulnerable Group Fund (VGF) [13, 14].

Multivariate Predictors of Coverage

Across all four nations, formal education and wealth are primary predictors of health insurance enrollment. As detailed in Table 2 and Table 3, multivariate logistic regression confirms that higher educational attainment and wealth quintiles significantly increase insurance uptake.

Table 2. Key Socio-economic Determinants of Coverage (Multivariate Analysis)

Determinant	General Association	Specific Statistical Example
Education	Strongly associated with increased coverage	Tanzania: Higher education 8x more likely to be insured
Wealth Status	Direct increase in likelihood per quintile	Kenya: Likelihood increases directly with wealth quintile
Occupation	Professional/Clerical jobs highly correlated	Higher enrolment among formal sector employees

Table 3. Multivariate Logistic Regression Analysis of Health Insurance Enrollment (Pooled DHS Data)

Independent Predictor	Adjusted Odds Ratio (aOR)	95% Confidence Interval	p-value
Educational Attainment			
No Formal Education (Ref)	1.00	-	-
Primary Education	1.42	1.28–1.57	<0.001
Secondary Education	285	2.56–3.18	<0.001
Higher (Tertiary) Education	6.74	5.92–7.68	<0.001
Household Wealth Quintile			

Poorest (Ref)	1.00	-	-
Poorer	1.35	1.21–1.50	<0.001
Middle	2.10	1.89–2.34	<0.001
Richer	3.45	3.10–3.84	<0.001
Richest	7.82	6.95–8.80	<0.001
Occupational Status			
Informal/Agricultural (Ref)	1.00		-
Professional/Clerical/Formal	2.94	2.70–3.2	<0.001

Strategic Policy Recommendations for UHC Acceleration

1. **Restoring Public Trust and Financial Stability (Ghana):** Secure ring-fenced tax revenue streams to reduce reliance on volatile state budgets and strictly prohibit public facilities from rejecting NHIS cardholders.
2. **Operationalizing Equity and Automation (Kenya):** Deploy automated subsidy mechanisms for lowest wealth quintiles and utilize mobile money platforms (e.g., M-Pesa) for informal micro-premium collections.
3. **Harmonization and Infrastructure Capitalization (Nigeria and Tanzania):** Consolidate fragmented schemes into unified national systems backed by innovative funding (sin taxes) and synchronized investments in supply-side health infrastructure.
4. **Prioritizing Female Education:** Target investments in women's formal education as a long-term strategy for enhancing health literacy and civic trust

Conclusion

The pursuit of UHC in sub-Saharan Africa requires a paradigm shift from voluntary frameworks to unified, mandatory national health insurance systems supported by automated state subsidies and supply-side infrastructure investments. Bridging socioeconomic gaps through education and wealth redistribution remains essential to ensuring health insurance functions as a universal right.

Conflict of Interest

The author declares that there is no conflict of interest.

Acknowledgements

The author expresses gratitude to Texila American University, ICF International, USAID, and the national statistical agencies of Ghana, Kenya, Nigeria, and Tanzania for providing access to the DHS datasets.

Ethical Approval

Ethical approval was not applicable for this study, as it involved secondary analysis of fully anonymized, publicly accessible Demographic and Health Survey (DHS) datasets.

Author Contributions

Isa Suleiman Abubakar is the sole author responsible for conceptualization, study design, statistical analysis, interpretation, drafting, and manuscript revision.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit section.

Data Availability

Secondary data utilized are publicly available through the DHS Program portal **(**https://dhsprogram.com**).**

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art007

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Influence of Religious Perceptions on Birth Control amongst Teenagers in Some Secondary Schools in Douala, Cameroon

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Cite this article as: Mohnchimbare Christina Mbongueh, Fankep Dihewou Alphonse Bertin Diheou, Mbabazi Asiati, Kamga Fouamno Henri Lucien. Influence of Religious Perceptions on Birth Control amongst Teenagers in Some Secondary Schools in Douala, Cameroon. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art007**

Received: 11.05.2026

Accepted: 29.08.2026

Published: 30.10.2026

Article Type: Original Research

Abstract *Unintended pregnancy among adolescents is a growing public health concern, particularly in sub-Saharan Africa where cultural and religious norms significantly influence sexual health behaviors. This study explores the level of awareness and the influence of religious perceptions on birth control among teenagers in selected secondary schools in Douala, Cameroon. Employing a cross-sectional design, data were collected through structured questionnaires targeting students aged 13–19 years. The findings reveal that although a portion of the respondents demonstrated basic awareness of birth control methods such as condoms and pills, significant gaps remain in their understanding of natural contraceptive methods, ovulation cycles, and access to reproductive health services. Religious beliefs, particularly within Christianity and Islam, were shown to play a central role in shaping attitudes toward contraceptive use, with many teenagers reporting that birth control was either discouraged or regarded as sinful. The study also identified multiple barriers to effective birth control usage, including socio-cultural taboos, poor parent-child communication on sexual matters, misinformation, fear of side effects, and economic limitations. The results underscore the urgent need for comprehensive sexual education programs tailored to adolescents, incorporating accurate reproductive health information while respecting religious and cultural contexts. Collaboration between schools, religious leaders, healthcare providers, and parents is essential to empower teenagers to make informed decisions about their sexual health. By bridging knowledge gaps and addressing religious concerns, stakeholders can help reduce unintended pregnancies and associated health and social burdens among Cameroonian adolescents.*

Keywords *Adolescent Reproductive Health, Birth Control, Religious Perceptions, Unintended Pregnancy.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art007

Introduction

Adolescence is a critical period of transition characterized by physical, emotional, and psychosocial changes, including the development of sexual and reproductive maturity. Despite this biological and social evolution, many adolescents remain poorly informed about reproductive health and birth control, particularly in developing regions like sub-Saharan Africa, where sexuality education is limited by cultural and religious barriers [1]. Globally, unintended pregnancies among adolescents aged 15–19 years are estimated at over 21 million annually, with nearly 50% being unplanned [2]. In sub-Saharan Africa, the adolescent birth rate is the highest in the world, with an incidence of 101 births per 1000 girls aged 15–19 years [3].

Worldwide, awareness of birth control remains inconsistent among adolescents. While over 70% of women of reproductive age in Europe and North America use contraception, the rate drops to less than 25% in parts of Western and Central Africa [4]. According to WHO estimates, about 252 million adolescents live in developing countries, and over 38 million are sexually active but do not want to become pregnant within the next two years. Of these, only 15 million use a modern contraceptive method, while 23 million have an unmet need [5]. This gap highlights both a knowledge deficit and limited access to youth-friendly sexual health services.

In Cameroon, early and unintended pregnancy among teenagers is a growing concern, with studies revealing prevalence rates of 24% among students in Yaoundé and 26% in Kumbo [6]. These pregnancies often result in serious health, social, and economic consequences. Teenage mothers face higher risks of eclampsia, puerperal endometritis, and systemic infections, while their babies are more likely to suffer from low birth weight, preterm birth, and neonatal complications [7]. The lack of knowledge about contraception, coupled with cultural and religious perceptions that often stigmatize its use, contributes significantly to this public health issue. Despite government efforts to integrate family planning into the minimum package of health services, modern contraceptive prevalence remains low. The 2011 Demographic and Health Survey reported a contraceptive use rate of 23.4% among sexually active women aged 15–49 years [8]. For adolescents, these figures are even lower due to stigma, fear, misinformation, and restrictive social norms [9].

Religious beliefs significantly shape individual and collective attitudes toward contraception. In many faith-based communities, especially among Christians and Muslims, contraception is often viewed as a violation of divine law or a promoter of sexual promiscuity [10]. The Roman Catholic Church, for example, recognizes only natural methods of family planning such as the rhythm method and condemns all artificial contraceptive methods [11]. Similarly, certain Islamic interpretations prohibit the use of contraceptives unless medically indicated, though some flexibility exists regarding temporary birth spacing [12].

Protestant and Pentecostal denominations present a more varied stance. While some churches permit contraceptive use within marriage, others discourage it as contrary to biblical teachings [13]. In Judaism, contraceptive use is often subject to the husband's approval and is generally discouraged unless for health or economic reasons [14]. These doctrinal positions influence the behavior of adherents, particularly adolescents, who are already vulnerable due to peer pressure, misinformation, and lack of autonomy.

In Cameroon, where Christianity and Islam are the dominant religions, the influence of religious teachings on reproductive choices is profound. Teenagers raised in conservative religious families may reject contraceptive use due to fear of sin, excommunication, or family

rejection [15]. This dilemma often leads to secrecy, unsafe sexual practices, and eventually, unintended pregnancies or unsafe abortions [16].

In addition to religious beliefs, other barriers compound teenagers' limited access to birth control. Socio-cultural norms, gender inequality, low parental communication about sexuality, and economic constraints play major roles. Most adolescents are not aware of the menstrual cycle, ovulation, or the timing of fertility, and many have misconceptions about the effectiveness and side effects of contraceptives [17]. Furthermore, access to family planning services is often limited by laws requiring parental consent, provider bias, and lack of confidentiality in health settings [18].

Economic barriers also persist. Adolescents from poor backgrounds may lack the financial means to purchase contraceptives or seek sexual health counseling. Moreover, inadequate sexuality education in schools fails to prepare teenagers for responsible sexual behavior. Studies have shown that comprehensive sexuality education reduces risky sexual behavior and delays sexual debut [19].

The increasing prevalence of unintended pregnancies among teenagers in Douala and the associated health and social implications call for urgent and context-specific interventions. In this context, religion and cultural beliefs remain double-edged swords: while they can serve as sources of moral guidance, they may also hinder access to vital reproductive health information and services. To develop effective strategies for preventing unintended teenage pregnancies, it is essential to understand the level of awareness about birth control and how religious perceptions shape reproductive decision-making among adolescents.

This study is justified by the persistent gap in reproductive health education and the high rate of teenage pregnancies in Cameroon. Previous research has focused mainly on adult populations or general contraceptive use without adequately exploring the intersection of awareness, religion, and adolescent reproductive choices. By focusing on teenagers in secondary schools in Douala, this research seeks to provide critical insights that could inform policy, health education, and community-based interventions. The objective of this study was therefore to assess the level of awareness and religious perceptions on birth control among teenagers in selected secondary schools in Douala.

Material and Methods

Study Design

This study employed a descriptive cross-sectional design using a quantitative approach. The design was chosen to assess the level of awareness and to explore the influence of religious perceptions on birth control practices among teenagers. The cross-sectional nature of the study allowed for the collection of data at a single point in time from a representative sample of secondary school students in Douala.

Study Setting

The study was conducted in the Douala IV municipality, located in the Littoral Region of Cameroon. This area includes a mixture of urban and peri-urban settings with a high concentration of secondary schools, both public and private. The population is religiously diverse, comprising Christians (Catholics, Protestants, and Pentecostals), Muslims, and other religious groups. The choice of this setting was motivated by the relatively high prevalence of teenage pregnancies reported in the area and the observed influence of religion on sexual health behavior.

Study Population

The study population consisted of teenagers (boys and girls) aged 13–19 years enrolled in selected secondary schools in Douala IV municipality. Participants were required to be attending school regularly and to provide

informed consent (and assent for those below 18 years, with parental or school approval).

Inclusion Criteria

1. Adolescents aged 13–19 years.
2. Enrolled in the selected secondary schools.
3. Willing to participate and provide informed consent (or assent with parental approval).

Exclusion Criteria

1. Teenagers outside the age range of 13–19 years.
2. Not present during the time of data collection.
3. Refusal to participate.

Sample Size Determination

The sample size was calculated using Cochran's formula for cross-sectional studies. The estimated prevalence of awareness of birth control was assumed at 50% for maximum variability. To account for potential non-responses or improperly completed questionnaires, a 10% buffer was added. A total of 422 students were thus targeted for inclusion in the study.

Sampling Technique

A multistage stratified random sampling technique was used. Schools were first stratified into public and private categories. Within each category, schools were randomly selected. From each selected school, students were stratified by class level (Form 3 to Upper Sixth), and participants were selected randomly using class registers as sampling frames.

Data Collection Tools and Procedure

Data were collected using a structured self-administered questionnaire designed in English and French. The questionnaire consisted of four sections:

1. Sociodemographic characteristics (age, sex, religion, school type, class level).
2. Awareness of birth control methods (knowledge, sources of information, understanding of fertility cycle, types of contraceptives).
3. Religious perceptions (attitudes influenced by religion, family/religious teachings on contraception).
4. Barriers to access (economic, cultural, institutional, and personal barriers).

The questionnaire was pre-tested on 30 students in a nearby school not selected for the main study to check for clarity, relevance, and reliability. Necessary modifications were made based on feedback.

Trained data collectors administered the questionnaire in the classrooms under supervision to ensure completeness and confidentiality. Anonymity was ensured by omitting names or identifiable personal data.

Results

Sociodemographic Characteristics of Respondents

A total of 412 questionnaires were correctly filled and returned, giving a response rate of 97.6%. Table 1 shows the sociodemographic characteristics of respondents. The mean age of participants was 16.2 ± 1.7 years. The majority were female (55.8%) and attended public schools (61.2%). Most respondents identified as Christian (82.5%), followed by Muslims (14.1%) and others (3.4%).

Table 1. Sociodemographic Characteristics of Respondents (N = 412)

Variable	Frequency (n)	Percentage (%)
Age Group		
13–15 years	142	34.5
16–17 years	178	43.2
18–19 years	92	22.3

Sex		
Male	182	44.2
Female	230	55.8
School Type		
Public	252	61.2
Private	160	38.8
Religious Affiliation		
Christian	340	82.5
Muslim	58	14.1
Others	14	3.4

Awareness on Birth Control Methods

Most respondents (77.4%) reported having heard about birth control methods. However, only 45.1% could correctly identify at least three modern contraceptive methods. The main sources of information were school health talks (41.8%), peers (25.5%), and media (19.7%). Awareness of the menstrual cycle and ovulation was limited: only 32.3% of respondents could correctly identify the fertile period.

Religious Perceptions on Birth Control

Table 2 shows the religious perceptions of participants on contraception. Approximately 61.7% of respondents reported that their religion discouraged the use of modern contraceptives. Among Christian students, 58.5% viewed contraception as a sin, whereas 70.7% of Muslim students expressed similar beliefs. The most accepted methods were natural methods like abstinence or the calendar method. A small minority (9.5%) reported being taught positively about birth control in religious settings.

Table 2. Religious Perceptions on Contraception

Statement	Agree (%)	Disagree (%)	Not Sure (%)
Contraception is forbidden by my religion	61.7	21.8	16.5
Using contraceptives promotes immorality	52.4	29.3	18.3
My religion supports only natural methods	57.2	22.1	20.7
I would be willing to use contraceptives if permitted	66.5	18.2	15.3

Barriers to Birth Control

Table 3 shows the barriers to contraceptive use as reported by participants. The most frequently reported barriers were lack of information (44.4%), fear of parental judgment (40.3%), religious restriction (36.7%), and fear of side effects (31.8%). Girls reported more religious and cultural resistance compared to boys ($p < 0.05$). Only 23.6% of respondents had ever discussed contraception with a parent or guardian. Chi-square analysis showed a statistically significant association between religious affiliation and attitudes toward contraceptive use ($\chi^2 = 11.82$, $p = 0.019$). Muslim and Pentecostal Christian students were significantly less likely to express willingness to use modern contraceptives, even if accessible.

Table 3. Reported Barriers to Contraceptive Use

Barrier	Frequency (n)	Percentage (%)
Lack of information	183	44.4
Religious or moral opposition	151	36.7
Fear of side effects	131	31.8
Fear of being judged by parents	166	40.3
Social stigma among peers	108	26.2

**Multiple Responses were Allowed*

Discussion

This study assessed awareness and religious perceptions of birth control among teenagers in secondary schools in Douala IV municipality. The findings revealed that while a considerable proportion of respondents had heard of birth control methods, their actual understanding and ability to use them correctly was limited. In addition, religious beliefs were found to significantly influence attitudes and practices related to contraception, contributing to persistent barriers and knowledge gaps.

Awareness of Birth Control Methods

The study found that a vast majority of respondents had heard of at least one method of birth control, with condoms being the most recognized. However, only 45.1% could correctly identify three or more methods, and knowledge of the menstrual cycle and ovulation was poor (32.3%). These findings are consistent with earlier research showing that although contraceptive awareness is widespread among adolescents in sub-Saharan Africa, comprehensive knowledge is often lacking [1, 2].

Similarly, a study by Darroch et al. estimated that out of 38 million sexually active adolescents in developing countries, only 15 million use modern contraception while 23 million have unmet needs due to misinformation and limited education [7]. In Cameroon, a low contraceptive prevalence rate of 23.4% among reproductive-aged women [8] underscores the limited reach of family planning education. Adolescents, in particular, may not access sexual health information due to taboos, limited school programs, and minimal parent-child communication [3, 18].

In our study, schools were the primary source of information (41.8%), followed by peers and media. This supports UNESCO's call for comprehensive sexuality education within formal curricula to foster accurate knowledge and informed choices [19]. However, peer-based knowledge is often fragmented and may perpetuate myths, further complicating adolescent decision-making [9].

Religious Perceptions and Contraceptive Use

Religious affiliation emerged as a strong predictor of contraceptive attitudes. A majority of respondents (61.7%) reported that their religion discouraged contraceptive use, and 57.2% indicated that only natural methods like abstinence or the calendar method were acceptable. Christian and Muslim students expressed similar levels of opposition, consistent with previous studies that documented doctrinal resistance to modern contraception [10-12].

The Roman Catholic Church, for example, endorses only natural methods and prohibits artificial contraception, viewing it as a violation of the procreative purpose of sexual activity [11]. Similarly, conservative Protestant denominations and Islamic teachings often discourage contraceptive use, especially among unmarried individuals [12-13]. In our study, Muslim respondents had the highest proportion of religious objection (70.7%), a figure that

aligns with Omran's findings on Islamic views of reproduction and birth control [12].

These findings corroborate Dzedong and Ako's observations that religious doctrines in Cameroon, particularly among youth, can instill guilt, fear of divine punishment, and discourage the uptake of sexual health services [15]. Additionally, in environments where contraception is viewed as promoting immorality (52.4% agreement in this study), adolescents are less likely to seek or use birth control, even if they are sexually active.

Barriers to Contraceptive Access and Use

The study identified several barriers to birth control, including lack of information (44.4%), fear of parental judgment (40.3%), and religious restriction (36.7%). These findings reinforce earlier research indicating that sociocultural norms, lack of adolescent-friendly services, and restrictive policies limit access to contraception [16-18]. WHO has emphasized that adolescents face unique challenges in accessing reproductive health services due to provider bias, limited confidentiality, and restrictive legal frameworks [18].

Additionally, this study found that only 23.6% of adolescents had ever discussed contraception with a parent or guardian. This deficit in intergenerational dialogue has been documented as a risk factor for early and unintended pregnancies [3]. Kumi-Kyereme and Awusabo-Asare also noted that adolescents with low parental communication are less likely to delay sexual initiation or use contraception consistently [17].

Economic and accessibility issues also compound the problem. Although Cameroon has integrated family planning into the basic health package [8], many adolescents still lack the financial means or knowledge to utilize services effectively. Previous studies have shown that adolescents from low-income households are more likely to experience unplanned pregnancies due to lack of contraceptive access and misinformation [7, 9].

Association Between Religion and Willingness to Use Contraceptives

The significant association ($p = 0.019$) between religious affiliation and willingness to use contraceptives highlights how doctrinal teachings impact individual health behaviors. This supports the findings of Chitando [13] and Freedman and Landy [14], who noted that doctrinal rigidity often translates into behavioral conservatism among religious youth. Even in the face of accurate information, religiously indoctrinated students may reject modern contraception due to perceived spiritual or moral conflict.

The tension between religious identity and reproductive autonomy is critical for policymakers and educators. It suggests that public health initiatives must adopt a culturally and religiously sensitive approach when promoting contraceptive use. Involving faith leaders in sexuality education initiatives may help bridge this gap, a strategy that UNFPA has successfully piloted through interfaith dialogues [10].

Implications for Public Health and Education

The findings of this study underscore the urgent need for expanded sexual health education programs tailored to adolescents, particularly those from religiously conservative backgrounds. Health education in schools must go beyond awareness and foster deeper understanding of reproductive biology, contraceptive options, and personal agency. According to WHO, empowering adolescents through education is one of the most effective strategies for reducing unintended pregnancy and maternal morbidity [1, 5].

Furthermore, engaging parents and religious leaders in adolescent reproductive health initiatives could help dismantle some of the cultural and religious barriers that hinder open

discussions on sexuality. UNESCO and other global bodies recommend multi-sectoral approaches that include schools, families, community-based organizations, and health services in designing youth-friendly programs [19, 20].

Conclusion

This study reveals significant gaps in contraceptive knowledge among teenagers in Douala and highlights how religious perceptions influence attitudes toward birth control. Despite relatively high awareness, misconceptions, religious constraints, and socio-cultural barriers prevent many adolescents from making informed reproductive choices. These findings support the need for comprehensive sexuality education and culturally sensitive interventions that respect religious diversity while safeguarding adolescent health.

Conflict of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

Ethical Approval

The study obtained ethical approval from the Institutional Ethics Committee of the Faculty of Health Sciences, University of Douala. Authorization to conduct the study was also obtained from the Regional Delegation of Secondary Education and from school authorities. Written informed consent was obtained from participants aged 18 and above. For those below 18, assent was obtained along with parental or guardian permission through school consent protocols. Participants were informed of their right to withdraw at any point without any consequences. Data were securely stored and used solely for academic purposes.

Acknowledgements

The authors sincerely appreciate all study participants, and the administration of the Nylon District Hospital that supported the conduct of this study.

Author Contributions

Mohnchimbare Christina Mbongueh: Conceptualization, Data Collection, Methodology, Formal Analysis, and Project Administration. Mbabazi Asiati and Fankep Dihewou Alphonse Bertin: Original Draft Preparation. Kamga Fouamno Henri Lucien: Supervision, Review and Editing.

Funding

The authors declare that this study received no specific grant or financial support from any funding agency in the public, commercial, or not-for-profit sectors.

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art008

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Evaluating Nutritional Policy Interventions for Managing Diabetes and Hypertension across Selected Health Facilities in Region Three, Guyana: A Mixed-Methods Study

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Cite this article as: Selese Melanee Shepherd-Holder, Michael Olabode Tomori. Evaluating Nutritional Policy Interventions for Diabetes and Hypertension across Selected Health Facilities in Region Three, Guyana: A Mixed-Methods Study. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art008**

Received: 26.08.2026

Accepted: 22.09.2026

Published: 30.10.2026

Article Type: Original Research

Abstract *The translation of nutritional policies into routine healthcare and sustainable dietary practices is crucial for the effective management of diabetes and hypertension. The Social Ecological Model (SEM) was employed in this study to evaluate the effect of nutritional policy interventions in some health facilities in Region Three, Guyana. A mixed-methods study was conducted at four public health facilities: the Goed Intent Health Centre (GIHC), the Parfaite Harmonie Health Centre (PHHC), Leonora Cottage Hospital (LCH) and the West Demerara Regional Hospital (WDRH). Quantitative data included 2,745 patients' records, 17 healthcare providers and facility assessments, complemented by qualitative evidence on patient and community experiences. Inferential and descriptive statistics, which included multivariable logistic regression, were integrated with thematic findings across SEM levels. The overall facility implementation was 40.0%; however, provider knowledge ranged from 45.0% to 60.0%, and reported practice ranged from 33.8% to 50.0%. Awareness of Food-Based Dietary Guidelines ranged from 51.7% to 75.6%, compared with 16.9%–48.2% for the Dietary Approaches to Stop Hypertension (DASH). Greater nutritional awareness was independently associated with high reported dietary practice (OR = 1.11, 95% CI: 1.10–1.12; $p < 0.001$). Cost and affordability constituted the predominant patient-level barrier (63.5%), followed by cultural and food norms (19.7%). Qualitative findings reinforced the influence of economic constraints, household food practices, provider capacity limitations and weaknesses in routine implementation. Nutritional policy implementation for diabetes and hypertension in Region Three is shaped by the interplay of patient, provider, organizational, community and policy influences. Strengthening implementation requires coordinated multilevel action that combines provider and facility support with affordable, culturally appropriate, and practical dietary guidance.*

Keywords *Diabetes, Dietary Practices, Guyana, Hypertension, Mixed Methods, Nutrition Policy, Social Ecological Model.*

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Introduction

Noncommunicable diseases (NCDs) continue to be a major public health challenge worldwide, responsible for three-quarters of deaths globally not due to pandemics [1]. Cardiovascular diseases and diabetes are major contributors to this burden, especially in low- and middle-income countries [1, 2]. By 2022, diabetes prevalence had reached around 830 million people worldwide [3] and 1.4 billion adults aged 30–79 years were estimated to be living with hypertension in 2024 [4]. These conditions require long-term clinical management and modification of behavioral risk factors, especially unhealthy dietary practices.

Nutrition is central to the prevention and management of diabetes and hypertension. Dietary patterns that limit excessive sodium, free sugars, and unhealthy fats while promoting appropriate intake of whole grains, vegetables, fruits and other nutrient-dense foods contribute to improved cardiometabolic health [5]. Consequently, international NCD strategies increasingly emphasize nutrition interventions as important components of primary healthcare and chronic disease management [2, 6]. But having evidence-based nutrition policies and recommendations in place does not guarantee their consistent implementation. To translate effectively, health care facilities need to have the appropriate systems and resources in place, providers need to be able to incorporate nutritional counselling into routine care, and patients need to be able to apply recommendations in their day-to-day circumstances. Economic conditions, household food practices, cultural preferences, health literacy and food availability may therefore influence whether nutritional guidance results in sustained dietary change. This challenge is particularly relevant in Guyana, where NCDs are a significant component of the disease burden. Cardiovascular disease and diabetes have been identified as major causes of illness and death through national surveillance, and large proportions of adults have hypertension and diabetes [7, 8].

Guyana has responded through health promotion, dietary guidance and primary healthcare interventions, which are supported by wider regional strategies for NCD prevention and control. Regional priorities similarly emphasize reducing modifiable risk factors and strengthening primary healthcare capacity for NCD management [9]. But the effect of these approaches depends on their translation into routine healthcare delivery and sustained patient behavior. FBDGs provide population-level guidance for healthy eating. DASH provides evidence-based recommendations with particular relevance to blood-pressure management. Translating such guidance into practice may be challenging, where recommended dietary changes compete with food costs, established cultural practices and household preferences. Evaluating nutritional interventions solely in terms of patient knowledge may therefore overlook important interpersonal, organizational and community influences.

The Social Ecological Model (SEM) provides an appropriate framework for examining these interacting factors. The SEM conceptualizes health behavior as being influenced by multiple interconnected levels, including individual, interpersonal, organizational, community and policy environments [10]. Within the present study, the individual level encompassed nutritional awareness, dietary practices, and selected clinical indicators; the interpersonal level included provider and household influences; the organizational level addressed provider capacity, facility readiness, resources, and documentation; the community level incorporated affordability, food access, and cultural practices; and the policy level considered the translation of nutritional guidance into healthcare delivery.

This multilevel perspective is crucial as weaknesses in implementation may occur at different levels simultaneously. A patient may know dietary recommendations but be unable to follow them because healthier options are too expensive or do not align with household practices. Similarly, providers may recognize the importance of nutritional counselling, but lack adequate training, educational material or organizational support. Thus, the availability of policy may have limited impact without mechanisms for implementation in health facilities and communities.

Despite the burden of diabetes and hypertension in Guyana, limited empirical evidence has examined how nutritional policy interventions operate simultaneously across facility, provider, patient and community levels within routine healthcare. Existing surveillance data provide valuable information on disease prevalence and behavioral risk factors but offer limited insight into the processes that connect nutritional guidance with clinical practice and patients' everyday experiences.

Accordingly, this study evaluated nutritional policy interventions for the management of diabetes and hypertension across selected health facilities in Region Three, Guyana, using a mixed-methods approach guided by the SEM. The evaluation examined facility implementation, provider knowledge and practice, patient nutritional awareness and reported dietary behavior, selected clinical indicators and economic, cultural and organizational barriers affecting implementation.

Materials and Methods

Study Design and Setting

A mixed-methods study was conducted across four public health facilities in Region Three (Essequibo Islands–West Demerara), Guyana: Goed Intent Health Centre (GIHC), Parfaite Harmonie Health Centre (PHHC), Leonora Cottage Hospital (LCH), and West Demerara Regional Hospital (WDRH). Quantitative and qualitative evidence was integrated to evaluate nutritional policy implementation for diabetes and hypertension across facility, provider, patient, and community levels.

Conceptual Framework

The assessment was guided by the SEM [10]. The implementation of the nutritional policy was examined across five interconnected levels: individual, interpersonal, organizational, community and policy. Individual-level measures included nutritional awareness, dietary practices and selected clinical indicators; interpersonal measures included provider counselling and household practices; organizational measures included provider capacity, facility readiness, resources and documentation; community measures included affordability, food access and cultural practices; and the policy level considered translation of nutritional guidance into routine healthcare.

The framework describes the interacting levels of policy/system, organizational, interpersonal, community and individual/patient that were used to guide the mixed-methods evaluation. Important areas include policy and guideline support; systems for facility readiness and implementation; provider counselling and influences on household behavior; affordability and cultural food practices; patient awareness; dietary practices and clinical indicators. Arrows indicate interactions between ecological levels, not causal links (Figure 1).

https://doi.org/10.21522/TIJAR.2014.13.04.Art008

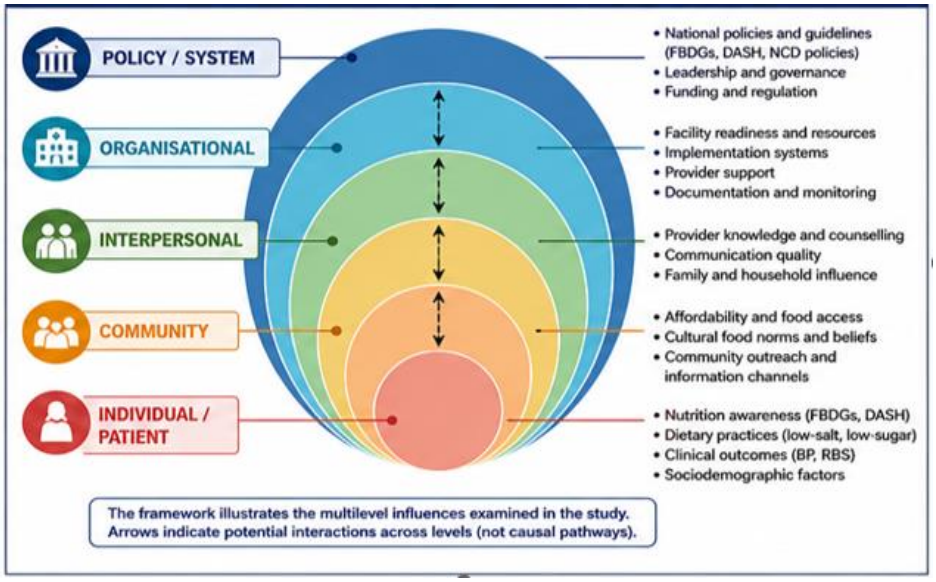


Figure 1. Social Ecological Model framework to evaluate nutritional policy interventions for diabetes and hypertension in Region Three, Guyana

Study Population and Data Sources

The quantitative component included 2,745 patients' records and 17 health care providers across the four facilities. The distribution of providers was as follows: five at GIHC, six at WDRH, four at PHHC and two at LCH. This included physicians, nurses and all other relevant allied health personnel in diabetes and hypertension care.

Patient records were eligible if they pertained to individuals receiving care for diabetes and/or hypertension and contained sufficient information for the variables required by the study. Valid blood-pressure measurements were available for 2,737 of the 2,745 patient records (99.7%). Random blood glucose (RBS) measurements suitable for analysis were available for 2,055 records (74.9%). Clinical analyses were restricted to records containing valid measurements for the corresponding indicator. Missing RBS measurements in patient records (25.1% overall) reflected routine health facility documentation and point-of-care testing gaps—such as unrecorded capillary readings or reagent availability—rather than study-level participant attrition or loss to follow-up.

Facility assessments examined organizational readiness and implementation conditions. Qualitative evidence from patients, provider and community components explored nutritional knowledge, counselling experiences, household and cultural influences, affordability, information and outreach and barriers to implementation.

Measures and Data Collection

Quantitative measures included facility implementation, policy preparedness, provider knowledge and reported nutrition practice. Additionally, Patient awareness and reported dietary behaviors, clinical indicators and barriers to nutritional recommendations. Patient awareness measures included familiarity with FBDGs and DASH. Dietary-practice measures included reported low-salt and low-sugar behaviors, as well as a composite measure of overall dietary practice. Provider knowledge and practice scores were expressed as percentages.

Clinical indicators pulled from patient records included blood pressure and RBS. The operational definition of elevated blood pressure was diastolic blood pressure ≥90 mmHg and systolic blood pressure >140 mmHg. RBS ≥200 mg/dL was used as a clinical operational flag for elevated glucose and was not interpreted independently to establish a new

diagnosis. The documentation of nutritional counselling was also reviewed.

Patient-level barriers were categorized as cost/affordability, cultural and food norms, lack of knowledge, time/workload, and availability/access. Qualitative data provided contextual information regarding these barriers and other influences on implementation. Standardized procedures and predefined variables were used across participating facilities.

Data Analysis

IBM SPSS Statistics version 29.0 was used for all quantitative data analyses. The data were checked for completeness, consistency and plausibility before analysis. Descriptive statistics were presented as frequencies, percentages and summary statistics as appropriate.

Chi-square tests were performed to assess differences in categorical clinical indicators among facilities, with Cramer's V used to assess effect size where appropriate. We also explored differences in availability of RBS measurements.

Factors associated with high reported dietary practice were determined using multivariable logistic regression. Predictors included age, health facility, percentage of nutritional awareness, and barrier category. Reported odds ratios (ORs), 95% confidence intervals (CIs) and p-values.

Qualitative data were analyzed thematically. Responses were coded and organized around recurring themes including nutritional knowledge, household and cultural food practices, affordability, information and outreach, implementation barriers and recommended support. Themes were mapped to relevant SEM levels.

Mixed-Methods Integration and Rigor

The quantitative and qualitative findings were combined and interpreted. Quantitative data were used to determine the distribution and size of implementation patterns, and qualitative data provided context-specific explanations. The areas of convergence and complementarity were organized across the levels of SEM and displayed in an integrated joint display.

Quantitative data were verified for completeness and implausible values; invalid clinical measurements were removed only from the respective analyses. Standardized coding was used in all facilities. Interpretation was bolstered by methodological triangulation across patient records, providers, facility assessments and qualitative evidence.

Results

Overview of the Evaluation

The mixed-methods evaluation was conducted at four public health facilities in Region Three. Quantitative data were collected from the records of 2,745 patients and 17 health care providers, as well as facility assessments and qualitative evidence. Table 1 details the components of the study and their connection with the SEM.

Table 1. Study Components and Contribution to the Mixed-Methods Evaluation

Component	Data source	Main measures	Primary SEM level
Patient clinical	2,745 patient records	Blood pressure, RBS, nutrition documentation	Individual/organisational
Patient nutrition	Patient-level data	FBDG/DASH awareness, dietary practices	Individual
Provider	17 healthcare providers	Knowledge, practice, implementation barriers	Interpersonal/organisational
Facility	Four health facilities	Readiness, resources, implementation	Organisational/policy

Contextual	Qualitative/community data	Affordability, culture, household practices, outreach	Interpersonal/community
Integration	Combined evidence	Convergence across implementation levels	Multilevel

Multilevel Implementation of Nutritional Policy

Providers' knowledge ranged from 45.0% to 60.0%, and reported provider practice ranged from 33.8% to 50.0%. However, given the small provider sample (n = 17), provider findings were interpreted descriptively. Training and limited educational materials were identified as important provider-level constraints. At the patient level, awareness of the FBDG ranged from 51.7% to 75.6%, while awareness of DASH was lower (16.9–48.2%). Reported low-salt practice ranged from 47.4% to 85.2% and low-sugar practice from 39.6% to 70.9%. However, cost/affordability (63.5%) and cultural/food norms (19.7%) were the dominant patient-level barriers (Table 2).

Table 2. Integrated Evaluation of Nutritional Policy Interventions across SEM Levels

SEM level	Domain	Key finding	Implementation issue
Individual	Awareness	FBDG: 51.7–75.6%; DASH: 16.9–48.2%	Uneven awareness
Individual	Dietary behaviour	Low-salt: 47.4–85.2%; low-sugar: 39.6–70.9%	Inconsistent dietary practices
Interpersonal	Counselling/household	Provider and household influences identified	Advice interacts with household practices
Organisational	Provider capacity	Knowledge: 45.0–60.0%; practice: 33.8–50.0%	Knowledge-practice gap
Organisational	Implementation	Overall: 40.0%	Limited operationalisation
Community	Affordability	63.5% of patient barriers	Economic constraints
Community	Cultural/food norms	19.7% of patient barriers	Established food practices
Policy	Readiness	60.0%	Readiness exceeds implementation

The figure summarizes key quantitative findings across the evaluated policy-to-practice pathway, from policy readiness and facility implementation through provider capacity, patient awareness and reported dietary practices to selected clinical indicators. Affordability and cultural/food norms are presented as contextual influences. Values represent ranges across participating facilities where applicable. The pathway represents levels of evaluation and should not be interpreted as demonstrating causal relationships (Figure 2).

https://doi.org/10.21522/TIJAR.2014.13.04.Art008

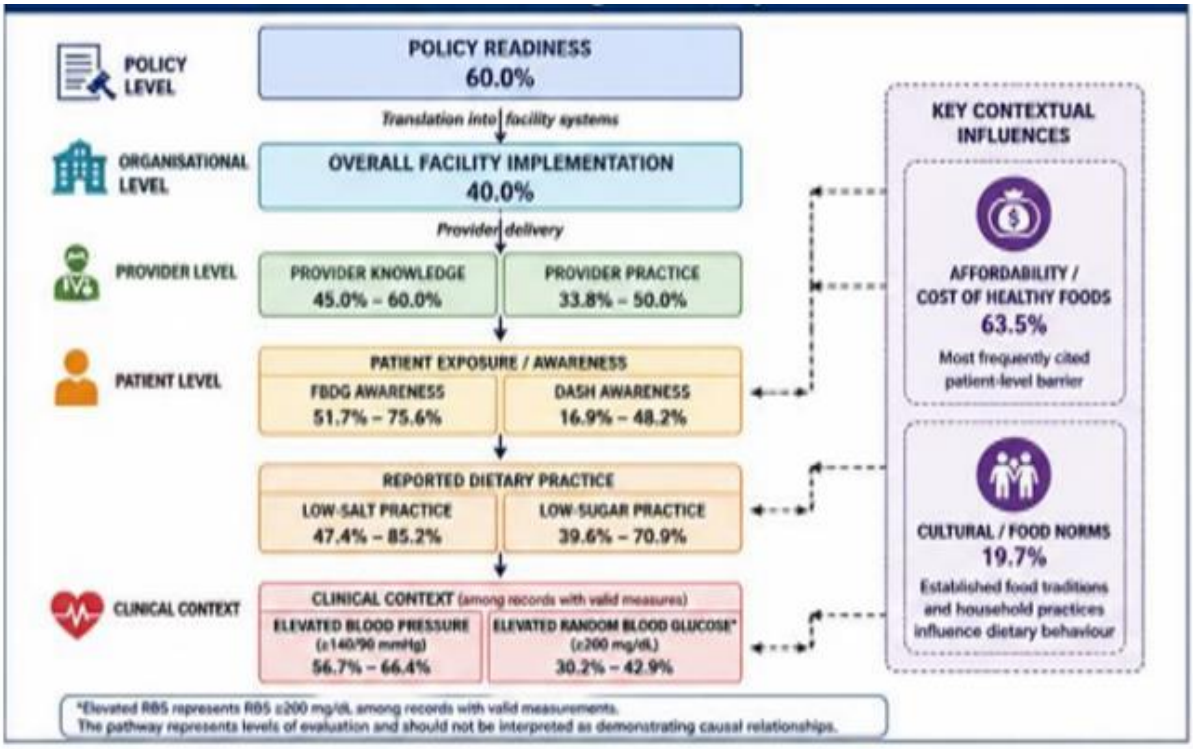


Figure 2. Multilevel Evaluation of Nutritional Policy Implementation across Selected Health Facilities in Region Three, Guyana

Factors Associated with Reported Dietary Practice

Of note, greater nutritional awareness was independently associated with higher reported dietary practice. However, for each 1-percentage-point increase in awareness was associated with approximately 11% higher adjusted odds for high dietary practice (OR = 1.11, 95% CI: 1.10–1.12; $p < 0.001$).

Facility was also independently associated with the outcome. Relative to GIHC, higher odds were observed at PHHC, WDRH and LCH (Table 3). The particularly large estimate for LCH should be interpreted with caution because of the high prevalence of the outcome and the distribution of observations across categories. Age was not statistically significant ($p = 0.170$). Culture/food norms were associated with lower adjusted odds of high dietary practice compared with availability/access (OR = 0.54, 95% CI: 0.29–0.99; $p = 0.047$).

Table 3. Multivariable Logistic Regression for High Reported Dietary Practice

Predictor	Adjusted OR	95% CI	p-value
Age	0.99	0.98–1.00	0.170
PHHC vs GIHC	3.40	2.33–4.94	<0.001
WDRH vs GIHC	10.12	6.85–14.95	<0.001
LCH vs GIHC	145.53	64.88–326.43	<0.001
Awareness (%)	1.11	1.10–1.12	<0.001
Culture/food norms vs availability/access	0.54	0.29–0.99	0.047

The substantial odds ratio observed for LCH relative to GIHC (OR $= \mathbf{145.53}, \mathbf{95\%}$ CI: $\mathbf{64.88 - 326.43}; \boldsymbol{p} < \mathbf{0.001}$) reflects sparse cell counts and quasi-complete separation within the cross-tabulation of facility type and reported dietary practices. Specifically, an exceptionally high proportion of patient records at LCH reported optimal dietary behaviors alongside near-zero occurrences of the reference category. While this confirms a strong directional trend toward higher reported compliance at LCH, the exact point estimate should be interpreted as a statistical artifact of category distribution rather than a true fold-increase in effect size.

Clinical Context

Valid blood pressure measurements were available in 2,737 (99.7%) patients' records. Elevated blood pressure (≥140/90 mmHg) ranged from 56.7% to 66.4% across facilities but differed significantly by facility ($\chi^2 = 22.32$, df = 3, $p < 0.001$); although the effect size was small (Cramer's V = 0.090).

RBS measurements suitable for analysis were available for 2,055 (74.9%) 'patients' records. Of these, 750 (36.5%) had RBS ≥200 mg/dL. Facility-specific proportions ranged from 30.2% to 42.9%, but differed significantly across facilities ($\chi^2 = 14.95$, df = 3, $p = 0.002$; Cramer's V = 0.085).

Notably, the availability of RBS measurements varied significantly across all facilities ($\chi^2 = 118.12$, df = 3, $p < 0.001$). The proportion of records that were without an analyzable RBS measurement ranged from 8.4% at LCH to 39.0% at PHHC. Consequently, RBS findings were interpreted from records with available measurements and in the clinical context, rather than as direct evidence of the effectiveness of nutritional intervention. This facility-level variation in analyzable glucose records represents operational testing and documentation differences across primary care settings, rather than study attrition.

Contextual and Qualitative Findings

Affordability was noted to be the most frequently identified patient-level barrier (63.5%; n = 1,743), followed by cultural/food norms (19.7%; n = 540), lack of knowledge (6.6%; n = 180), time/workload (5.9%; n = 161) and availability/access (4.4%; n = 121).

Qualitative findings complemented these patterns. Cultural and household food practices represented 20.3% of the broader focus-group coded responses, while information and outreach channels accounted for 18.1%. An analysis of the community outreach data showed that acceptability and learning accounted for 23.7% of coded responses, indicating some receptiveness to nutrition education. However, training limitations, inadequate educational materials and weak documentation of nutritional counselling further emerged as organizational constraints.

Mixed-Methods Integration

The integration showed that the implementation of nutritional policy was influenced by interacting factors across SEM levels (Table 4). Increased awareness of dietary practice was reported, but implementation was influenced by affordability and household food practices. Provider knowledge was also limited in areas where training, resources and organizational systems did not support consistent counselling (Figure 3).

Table 4. Mixed-Methods Joint Display of Nutritional Policy Implementation

Issue	Quantitative evidence	Qualitative/contextual evidence	Integrated interpretation
Awareness	FBDG 51.7–75.6%; DASH 16.9–48.2%	Importance of information/outreach	Nutrition messages reach patients unevenly

Awareness and practice	OR = 1.11 (95% CI: 1.10–1.12)	Participants valued nutrition learning	Education supports behaviour but is insufficient alone
Affordability	63.5%	Economic constraints	Financial feasibility limits implementation
Culture/household	19.7%; OR = 0.54	Established food practices	Counselling requires cultural adaptation
Provider capacity	Knowledge 45.0–60.0%; practice 33.8–50.0%	Training/material gaps	Organisational support is required
Facility systems	Implementation 40.0%	Documentation/resource weaknesses	Routine implementation remains limited
Community outreach	23.7% outreach acceptability/learning	Receptiveness to education	Community delivery offers an implementation opportunity
Clinical context	Elevated BP 56.7–66.4%; RBS 30.2–42.9%*	—	Persistent clinical risk supports stronger intervention

**RBS ≥200 mg/dL among records with valid measurements.*

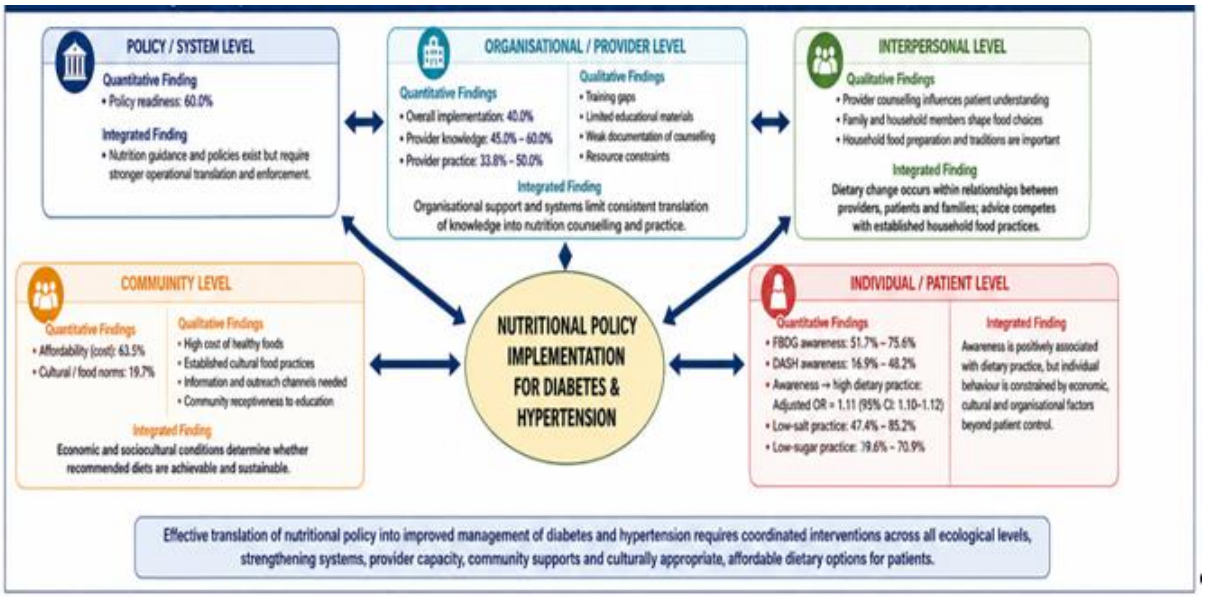


Figure 3. Integrated mixed-methods evaluation of nutritional policy interventions across Social Ecological Model levels in Region Three, Guyana

Quantitative and qualitative findings are integrated across individual, interpersonal, organizational, community and policy/system levels. Patient awareness was positively associated with high reported dietary practice (adjusted OR = 1.11, 95% CI: 1.10–1.12). Affordability, cultural and household food practices, provider capacity limitations and organizational weaknesses constrained implementation. The integrated findings demonstrated that effective translation of nutritional policy into diabetes and hypertension management requires coordinated

interventions across ecological levels, rather than reliance on patient education alone.

Discussion

Principal Findings

This mixed-methods study identified critical operational gaps in the implementation of nutritional policy interventions for diabetes and hypertension across selected health facilities in Region Three, Guyana. The findings indicate that implementation is shaped by complex, interacting factors across the Social Ecological Model (SEM) rather than by patient knowledge or individual behavioral choices alone. Notably, policy readiness exceeded facility-level execution; healthcare provider knowledge was moderate but insufficiently translated into clinical practice; patient awareness demonstrated a positive association with reported dietary behaviors; and socio-economic constraints—principally affordability and cultural food norms—profoundly influenced the feasibility of dietary modification. Among patients with available diagnostic records, this implementation gap was accompanied by a high prevalence of elevated blood pressure and variable glycemic control. Collectively, these empirical observations underscore that optimizing the nutritional management of chronic noncommunicable diseases requires coordinated strategies spanning individual, interpersonal, organizational, community, and policy domains.

Policy, Facility, and Provider Implementation

The observed disparity between national policy readiness (60.0%) and overall facility implementation (40.0%) demonstrates that the formulation and dissemination of nutritional guidelines do not automatically guarantee their integration into routine primary healthcare delivery. Sustainable policy translation requires robust organizational infrastructure, structured provider training, standardized counselling tools, workflow compatibility, and routine monitoring mechanisms. These findings align with implementation science literature, which consistently demonstrates that organizational readiness and structural capacity govern the degree to which evidence-based interventions become embedded in clinical practice [11, 12].

Findings at the provider level further illustrate this translation gap. While provider knowledge scores ranged from 45.0% to 60.0%, reported clinical practice lagged at 33.8% to 50.0%. Although the modest provider sample size $(n = 17)$ necessitates cautious interpretation, qualitative evidence corroborated these quantitative trends by identifying systemic constraints, particularly the lack of structured professional training and a shortage of patient educational materials. Consequently, expanding provider knowledge is necessary but insufficient unless accompanied by practical counseling resources and institutional support systems.

Furthermore, documentation of nutritional counselling was exceptionally sparse across participating facilities. Patient accounts indicated that oral dietary guidance was delivered more frequently than was recorded in formal clinical charts. Inconsistent documentation undermines continuity of care and impedes systematic auditing of preventive health services. This finding aligns with broader regional literature highlighting deficiencies in lifestyle counselling documentation within Caribbean health systems; for example, a multi-country survey of 1,661 patients with diabetes reported that only 32% had documented dietary counselling in their medical records over a 12-month period [17]. Addressing this documentation gap in Region Three will require standardized, low-burden recording tools embedded within routine clinical workflows.

Patient Awareness and Dietary Behavior

Multivariable regression analysis demonstrated that patient nutritional awareness was an independent positive predictor of high

reported dietary practice ($OR = 1.11, 95\%$ CI: $1.10 - 1.12; p < 0.001$). Each percentage-point increase in awareness was associated with an 11% increase in the adjusted odds of adopting favorable dietary behaviors, confirming the continued value of patient-centered health education in diabetes and hypertension management.

However, patient familiarity differed significantly depending on the type of nutritional guidelines. Awareness of general Food-Based Dietary Guidelines (FBDGs) ranged from 51.7% to 75.6%, whereas awareness of the condition-specific Dietary Approaches to Stop Hypertension (DASH) model was markedly lower (16.9%–48.2%). This discrepancy suggests that broad healthy-eating communication reaches the patient population more effectively than therapeutic dietary strategies. Structured dietary patterns, particularly sodium reduction and the DASH diet, possess a strong evidentiary base for blood pressure attenuation [13, 14], just as tailored medical nutrition therapy remains fundamental to glycemic control [15].

Nevertheless, the statistical association between awareness and reported behavior must be contextualized within patients' broader socio-ecological reality. While health literacy provides a foundational prerequisite for behavioral change, patients cannot successfully operationalize dietary knowledge without enabling economic and social conditions.

Affordability and Sociocultural Influences

Financial constraints constituted the single most prevalent patient-level barrier, accounting for 63.5% of reported obstacles. This finding demonstrates that non-adherence to dietary recommendations is largely driven by structural economic realities rather than a lack of patient motivation or health literacy. Global evidence corroborates that food affordability remains a primary determinant of healthy diet acquisition [16], a challenge well-documented across the Caribbean. Empirical studies in the Eastern Caribbean have established a direct link between perceived food costs and reduced fruit and vegetable consumption [19], while health economics research among low-income Caribbean households indicates that securing a nutritionally adequate diet can absorb a disproportionate share of total household income [20].

These economic realities have direct operational implications for clinical nutrition counselling in Region Three. Standardized recommendations featuring unaffordable foods offer limited therapeutic value to patients facing financial strain. Clinical guidance must therefore pivot toward affordable, locally sourced nutrient-dense foods, practical portion management, and cost-neutral adaptations of traditional meals.

Cultural and food norms emerged as the second most prominent barrier (19.7%). Patients identifying cultural norms as their primary constraint exhibited lower adjusted odds of high dietary practice compared to those citing physical availability or access ($OR = 0.54, 95\%$ CI: $0.29 - 0.99; p = 0.047$). Qualitative data reinforced these quantitative observations, underscoring that household food preparation patterns and deep-seated culinary traditions exert a strong influence on dietary behavior. These findings closely parallel qualitative evidence from Montserrat, where food economics, family dynamics, cultural habits, and taste preferences collectively governed adherence to the DASH diet among adults with hypertension [18].

These observations emphasize the interpersonal and community constructs of the SEM. Because food purchasing and preparation decisions typically occur at the household level rather than in isolation, culturally sensitive counselling should emphasize modifying familiar recipes rather than imposing alienating dietary shifts. Incorporating family members into nutrition education sessions represents a

strategic approach to fostering sustained household-level dietary change.

Additionally, community outreach represents an underutilized implementation mechanism. Qualitative findings indicated substantial patient receptivity to community-based educational channels (23.7% acceptability). Expanding community outreach can effectively extend clinical counselling into non-formal spaces, provided that educational content prioritizes practical culinary adaptations and budget-conscious food selection over abstract dietary guidelines.

Clinical Context and Interpretation

Clinical record audits revealed a substantial burden of uncontrolled risk factors across participating facilities, with elevated blood pressure ($\geq 140/90$ mmHg) ranging from 56.7% to 66.4% and elevated random blood glucose (≥ 200 mg/dL) ranging from 30.2% to 42.9% among valid measurements. While these metrics illustrate the heavy cardiometabolic disease burden in the study population, they should not be interpreted as direct measures of nutritional policy efficacy. Blood pressure and glycemic parameters are confounded by disease duration, pharmacotherapy adherence, comorbid conditions, physical activity, and broader healthcare access factors that fell outside the scope of this evaluation.

Furthermore, substantial variance in the availability of analyzable glucose records across facilities (missingness ranging from 8.4% to 39.0%) highlights underlying data collection and documentation gaps in primary care settings. Consequently, these clinical findings serve to illustrate the urgent health context requiring intervention rather than establishing a direct causal effect of policy implementation on biological endpoints. Because missing glucose data were attributable to systemic primary care documentation gaps rather than participant dropouts, clinical findings reflect the subset of records with complete diagnostic entries under real-world service conditions.

Integrated SEM and Mixed-Methods Interpretation

The integration of quantitative and qualitative data demonstrates that nutritional policy implementation operates as a dynamic, multi-tiered process across the SEM. At the individual level, nutritional awareness positively predicts reported dietary practice. At the interpersonal level, provider communication and household dynamics govern daily dietary choices. At the organizational level, delivery is constrained by provider capacity gaps, resource deficits, and sub-optimal clinical documentation. At the community level, financial limitations and cultural norms define the boundaries of practical dietary compliance. Finally, at the policy level, structural gaps persist between administrative formulation and facility-level execution.

Crucially, these ecological tiers interact continuously. Enhancing patient literacy yields diminishing returns if healthy food options remain economically unattainable. Upskilling clinicians without supplying educational tools or structural support fails to translate into routine counselling practice. Likewise, establishing policy guidelines without operational infrastructure deepens the divide between intended strategy and clinical reality.

The mixed-methods approach proved essential for capturing these multi-level interactions: quantitative metrics established the magnitude and distribution of implementation gaps, while qualitative findings provided explanatory context regarding the structural mechanisms driving those gaps. Ultimately, improving nutritional policy implementation in Region Three requires moving beyond isolated patient education toward a synchronized, multi-level framework that aligns facility infrastructure, provider

capacity, and community support with the socio-economic realities of the population.

Implications for Policy and Practice

The findings have important implications for strengthening nutritional interventions in the management of diabetes and hypertension in Region Three. Nutritional policy implementation should extend beyond the dissemination of guidelines to include mechanisms that support their consistent translation into routine clinical practice. The observed difference between policy readiness and facility implementation indicates a need for stronger operational systems, including standardized counselling procedures, appropriate educational resources, routine documentation and monitoring of nutrition-related care.

At the provider level, continuing professional development should strengthen practical competencies in dietary counselling for diabetes and hypertension. Training should emphasize the communication of FBDGs, DASH principles, salt and sugar reduction and the adaptation of recommendations to patients' economic and cultural circumstances. Simple documentation tools incorporated into existing patient records may improve continuity and monitoring without creating unnecessarily complex administrative requirements.

At the patient and community levels, the strong association between nutritional awareness and reported dietary practice supports continued nutrition education. However, the predominance of affordability and cultural food norms as barriers has demonstrated that education alone is insufficient. Dietary counselling should priorities affordable, locally available foods and culturally acceptable modifications of commonly consumed meals. Wherever feasible, household members should be included in the planning processes, since food purchasing, preparation and consumption often occur within family settings.

Community outreach provides an additional opportunity to reinforce facility-based counselling. Collaboration among healthcare facilities, community health workers, and other relevant stakeholders could support practical nutrition education that is tailored to local circumstances. Overall, the implementation of nutritional policy should be approached as a coordinated, multilevel process that links policy guidance to facility systems, provider capacity, household realities and community support.

Strengths and Limitations

A major strength of this study was its mixed-methods design, which integrated patient-record, provider, facility and qualitative evidence to evaluate the implementation of nutritional policies across multiple SEM levels. The inclusion of 2,745 patient records across four health facilities provided a substantial quantitative basis for examining nutritional practices and clinical indicators. Integration of quantitative and qualitative findings also enabled the interpretation of implementation gaps within their organizational, economic, cultural, and community contexts.

Several limitations should be considered. Dietary practices were primarily self-reported and may therefore have been affected by recall and social-desirability bias. The provider sample was small ($n = 17$), limiting the precision and generalizability of provider-level comparisons. Causal conclusions about relationships among policy implementation, dietary practices and clinical indicators are precluded by the observational nature of the study. The very large facility-specific odds ratio observed for high dietary practice at LCH should therefore be interpreted with caution.

RBS measurements suitable for analysis were available in 74.9% of patient records and availability varied significantly across facilities. Glucose findings therefore represent patients with analyzable measurements and may not reflect the entire study population.

Clinical outcomes may also have been influenced by medication adherence, disease duration, comorbidities, and other factors not fully assessed. Finally, the study involved selected public health facilities in Region Three; findings may therefore not be directly generalizable to all healthcare facilities in Guyana.

Recommendations

1. **Strengthen facility-level implementation systems.** Health facilities should establish standardized procedures for delivering, documenting and monitoring nutritional counselling as part of the routine diabetes and hypertension care.
2. **Enhance healthcare-provider capacity.** Continuing professional development should strengthen one's practical competencies in the FBDGs, DASH principles, salt and sugar reduction, culturally responsive counselling and the communication of affordable dietary options.
3. **Provide practical and culturally appropriate patient education.** Nutritional guidelines should emphasize locally available foods, affordable meal choices and realistic modifications of commonly consumed foods rather than relying primarily on generic dietary messages.
4. **Expand community and household engagement.** Nutrition outreach should complement facility-based counselling and, where appropriate, should involve family members, who influence food purchasing and preparation.
5. **Strengthen monitoring and evaluation.** Routine assessment of counselling delivery, nutritional documentation, patient awareness, dietary practices and relevant clinical indicators should be incorporated into quality-improvement processes. Future research should evaluate the effectiveness and cost-effectiveness of multilevel nutritional interventions, as well as their longer-term influence on dietary and clinical outcomes.

In summary, these measures should be implemented as complementary components of a coordinated approach, rather than interventions in isolation.

Conclusion

This mixed-methods study demonstrated that implementation of nutritional policy interventions for diabetes and hypertension across selected health facilities in Region Three, Guyana, is influenced by many interacting factors at multiple levels of the SEM. Although nutritional policy guidelines and patient education were evident, gaps remained in facility implementation, provider practice, counselling documentation and awareness of specific dietary approaches. Greater patient awareness was associated with better-reported dietary practices; however, affordability, cultural food norms and household practices influenced the feasibility of sustained dietary change.

Improving nutritional management therefore requires more than increasing patient knowledge. Effective policy translation depends on strengthening facility systems and providers' capacity while ensuring that dietary recommendations are affordable, culturally appropriate and practical within patients' everyday environments. Coordinated action across policy, organizational, provider, household, community, and individual levels is essential to strengthen nutritional interventions and support the management of diabetes and hypertension in Region Three.

Conflict of Interest

The authors declare no conflict of interest.

Consent for Publication

Not applicable. No individually identifiable participant information is presented in this manuscript.

Acknowledgements

The authors would like to thank the Ministry of Health, Guyana, the management and health care staff of the participating health facilities in Region Three as well as all patients, health care providers and community participants whose contributions made this study possible. The author also thanks those who have helped with the research for their academic and technical support.

Ethics Approval

The study was approved by the Ministry of Health, Guyana Institutional Review Board (IRB) (Approval Reference 029/2026). Administrative permission was obtained from the respective health facilities. Participation in the primary data-collection components was voluntary, and informed consent was obtained in accordance with the approved research protocol. Confidentiality and privacy were maintained during the data collection, analysis and reporting

Author Contributions

Selese Melanee Shepherd-Holder: Conceptualization, Methodology, Investigation, Formal Analysis, Writing – Original Draft and Final. Michael Olabode Tomori: Supervision, Project Administration, Writing – Review & Editing.

Data Availability

The datasets used and analyzed in this current study are not publicly available due to ethical and institutional restrictions on health service and participant information. De-identified data are available from the corresponding author on reasonable request and approval from the respective institutional and ethical authorities.

Funding

This research received no external funding. The study was solely funded by the principal author, Selese Melanee Shepherd-Holder.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art009

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Assessment of Environmental Factors Associated with Endemic Cholera in Lukanga Swamps of Kapiri Mposhi District in Central Province of Zambia

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Cite this article as: Simeon Sikwiiya, Meki Deborah Chisala, Roma Chilengi. Assessment of Environmental Factors Associated with Endemic Cholera in Lukanga Swamps of Kapiri Mposhi District in Central Province of Zambia. Texila Int J Acad Res. 2026;13(4).
https://doi.org/10.21522/TIJAR.2014.13.04.Art009

Received: 31.05.2026
Accepted: 25.08.2026
Published: 30.10.2026

Article Type: Original Research

Abstract *Cholera, an acute diarrheal disease, is caused by the bacterium Vibrio cholerae and is usually transmitted through contaminated water or food. This study assessed the environmental factors associated with endemic cholera in Lukanga Swamps from January 2010 to January, 2018. This was a Time Series Correlational Study. Air temperature and precipitation data were collected from 19 lagoons using satellite remote sensing from 2010 to 2016. Water samples were also collected for analysis. Data were analyzed in Stata Version 14. Results from the standard Poisson regression (PR) model were compared with those from the Zero-Inflated negative binomial regression (ZINBR) to determine the best-fit model. The study reported 133 cholera cases during the study period. It found that increased rainfall was associated with decreased risk of cholera cases (IRR = 0.992, 95% CI: 0.988 – 0.997, P=0.002). We also found that a 1-degree increase in temperature increased the risk of cholera cases by 27%, which was statistically significant (IRR = 1.265, 95% CI: 1.142–1.402, P = 0.0001). Water quality monitoring tests from 19 lagoons revealed that 19/36 (53%) of water samples had faecal coliforms. The study further revealed a pH range of 7.1 to 8.5 or higher. V. cholerae was not isolated from 164 water samples. In conclusion, air temperature was strongly associated with cholera outbreaks in the Lukanga Swamps. Increased rainfall was also associated with a decreased risk of cholera cases. Therefore, a multifaceted approach should be used to prevent and control cholera in Lukanga Swamps.*

Keywords *Endemic Cholera, Environmental Factors, Lukanga SWAMPS.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art009

Background

Cholera, an acute diarrheal disease caused by the bacterium Vibrio cholerae, is usually transmitted through water or food contaminated with faecal matter [1]. About 1.4- 4.3 million annual global cholera cases are reported, and deaths range from 28,000 to 142,000. Cholera has become endemic in Africa, with large epidemics occurring in different parts of the continent. Over the course of 2007 to 2011, more than 100,000 cases of cholera were reported to WHO annually from at least 20 African countries, with case fatality rates reaching about 3% [2]. In Zambia, cholera has been endemic since its first occurrence in 1977/1978, just like in other areas of Africa [3]. Recent studies have established that cholera occurs in three forms: epidemic (a sudden outbreak in a previously relatively disease-free region and primarily inland), endemic (recurring essentially annually and predominantly along coastal regions), and mixed-mode (a combination of epidemic and endemic disease occurrence) [4].

According to Jutla in 2015 [4], air temperature, precipitation, humidity, water pH, water quality, and sanitation were associated with cholera outbreaks. In Kapiri Mposhi district, there has been a problem of cholera for many years emanating from the Lukanga Swamps. Lukanga Swamps recorded 42 cases in 2012, 47 cases in 2014, 6 cases in 2015, and 30 cases in 2016, respectively [5]. There is little information available for Lukanga Swamps on environmental factors associated with endemic cholera. The main objective of this study was to assess environmental factors associated with endemic cholera in Lukanga Swamps from 2010 to 2018. It specifically also sought to assess the association between environmental conditions (temperature and precipitation) and cholera cases in Lukanga Swamps from January, 2010 to December, 2016.

Methods

Study Area

This study was conducted in Lukanga Swamps in Central Province of Zambia as indicated in Figure 1. The catchment area of the wetland is 13,520 km2. The Lukanga Swamp is located approximately 50 km west of Kapiri Mposhi District, in the Central Province of Zambia, within the catchment of the Kafue River. It is estimated that about 60,000 people live in, or close to, the wetland [6].

Study Type

A quantitative time-series correlational design was employed to examine the association between environmental factors and cholera epidemics in the Lukanga Swamps. The design allowed the examination of temporal patterns and statistical relationships between environmental variables and cholera incidence without manipulating any study variable. A time-series design involves the collection and analysis of observations measured at successive points in time, enabling the identification of temporal patterns, seasonal variations, and long-term trends in disease occurrence and environmental conditions.

Sampling Procedure

This study employed total sampling, including all 19 accessible lagoons in the Lukanga Swamps through Kapiri Mposhi district, from which cholera had previously broken out.

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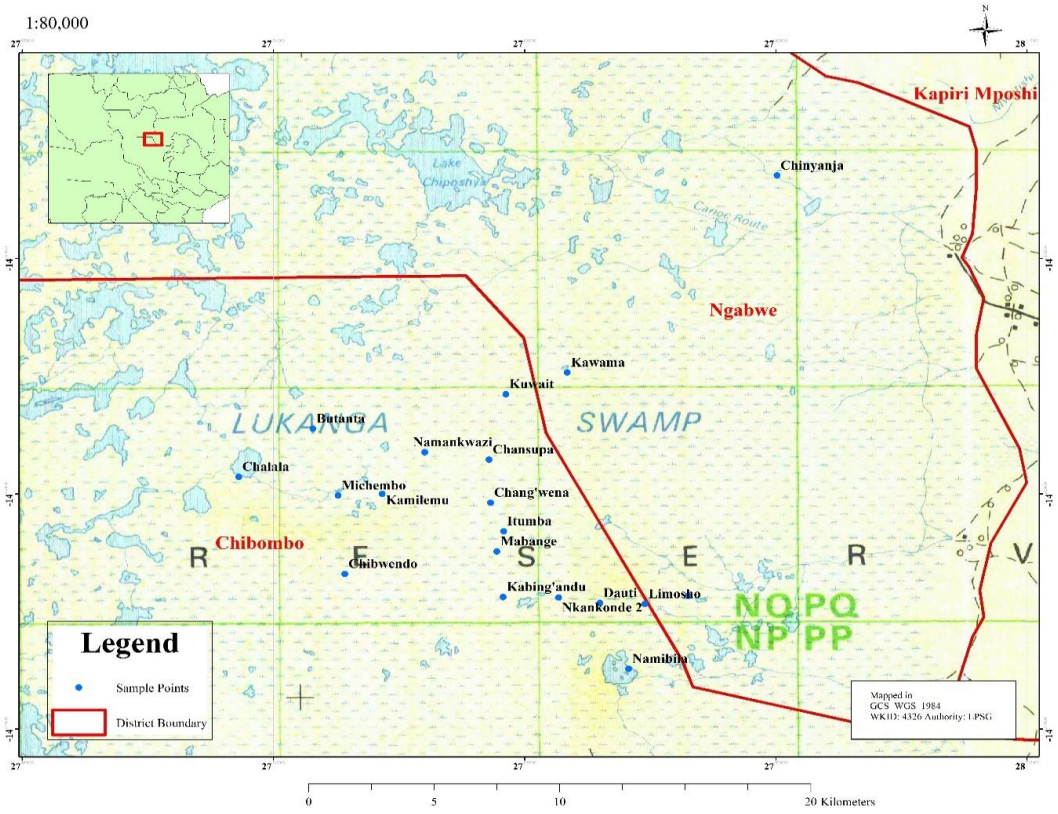


Figure 1. Study Site Map with Water Sample Collection Points Dotted in Blue

Data Collection Techniques and Tools

Satellite remote sensing was used to obtain information for environmental variables including: air temperature and precipitation for the period of 2010 to 2016. Water quality monitoring and pH were also determined from September, 2017 to January 2018 through water sample collection and analysis.In addition, the sanitation condition of the Lukanga Swamps was also assessed through observations.

Study Variables

The following variables were considered in this study: Cholera cases were the outcome variable, while Air temperature, Rainfall, sanitation, Potential Hydrogen, and Water quality were predictor variables.

Data for Cholera Cases

Information for cholera cases was obtained from the Kapiri Mposhi District Health Office Information System database and from the Provincial Health Office line listing database from January, 2010 to December, 2016.

Environmental Data (Air Temperature and Precipitation)

Historic data for Environmental factors such as air temperature and precipitation were collected from all 19 lagoons using satellite remote sensing.Due to a lack of weather information in the study area, rainfall and temperature estimates were collected from Tropical Applications of Meteorology using Satellite and ground-based observations [8]. TAMSAT was developed by the University of Reading in 1977 and has an archive of data from 1983 to the present [8]. TAMSAT is derived from a combination of geostationary Meteosat data and gauge observations using a calibration approach that exploits both data sets [9]. The primary objective has been to render historic and near real-time precipitation estimates for drought monitoring in sub-Saharan Africa where there is a lack or complete absence of in situ observations [10].

TAMSAT provides decadal (10-day) rainfall data at 4 kilometres spatial resolution across the whole African continent.

Rainfall and temperature data were collected in the ArcMap protocol of ArcGIS, where decadal data within each month were summed to derive a monthly value. Within ArcMap, monthly rainfall and temperature values from January, 2010 to December 2016 were extracted at each of the 19 sample points using the *Extract Multi Values to Points* tool in the Spatial Analyst toolbox, resulting in a table.

Water Sampling

Water samples were collected from all lagoons under study for five months from September, 2017 to January, 2018 to assess the presence of faecal coliforms and *Vibrio cholerae*. The total number of water samples planned to be collected was 190 from the 19 lagoons under study. However, we managed to collect 164 water samples due to logistical challenges. For quality control purposes, water samples were delivered to two different laboratories: 90 samples to the Food and Drugs Control Laboratory and 74 samples to the Centre for Infectious Diseases and Research in Zambia (CIDRZ) Laboratory, both in Lusaka, for analysis. Sampling techniques were upheld to maintain the efficacy of the samples. Water samples were collected using sterilized 500 mL bottles for bacteriological analysis to the Food and Drugs Control Laboratory, while Whatman 903 filter papers were used to collect and store water samples for CIDRZ Laboratory for isolation of *V. cholerae*.

Procedure taken at Food and Drugs Lab: Water samples were enriched in alkaline peptone broth (1% peptone, 1% Sodium Chloride (NaCl, pH 8.4), using a concentration of broth relative to sample volume. Enriched cultures were incubated for 6 to 8 hours at 35 degrees Celsius, then a loopful of the enrichment broth was streaked onto thiosulfate-citrate-bile salts-sucrose (TCBS) agar, and the plates were incubated at 35 degrees for 18 to 24 hours. Suspected *V. cholerae* colonies appear yellow, a result of sucrose fermentation.

Procedure taken at Centre for Infectious Diseases and Research in Zambia (CIDRZ): Water samples stored on Whatman 903 filter papers and kept at room temperature were delivered to CIDRZ every month for the detection of ***Vibrio*** *cholerae* 01/0139 by Polymerase chain reaction (PCR). In order to perform PCR, deoxyribonucleic acid (DNA) had to be extracted from the bacterial cells. Thermal shock was used to lyse the bacterial cells that were present on the filter papers and release the DNA. The Chelex matrix was used to absorb cell lysis products that interfere with the PCR amplification process. Then, a multiplex PCR assay for rapid detection of toxigenic *Vibrio cholerae* 01 and 0139 was comprehensively done.

Potential Hydrogen Levels

The pH level, which is important in creating a conducive environment for the growth of microorganisms including *V. cholerae*, was measured on a monthly basis from each lagoon. Water samples from each study lagoon were collected for five months in a one-litre container and were submitted to Mahatma Gandhi Memorial Clinic in Kabwe for pH analysis in a Porter Lab. The readings were recorded on the checklist formulated for that purpose. However, the instrument used to measure pH was calibrated from 0 to 8.5, and above 8.5, it was giving a greater than sign, making it difficult to know the exact pH readings for all those that indicated the greater than sign.

Assessment of Sanitation Status in 19 Lagoons of Lukanga Swamps

The evaluation of sanitation status in all 19 sampled lagoons was conducted through observations, as initially designed, and by

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asking where people answered the call of nature within the swamps.

Data Processing and Analysis

Data on temperature and precipitation were collected for 84 months from January 2010 to December 2016, and average monthly temperatures and precipitation were reported. A total of 164 water samples for water quality monitoring were collected from 19 lagoons for five months from September, 2017 to January, 2018.Data were entered in Microsoft Excel and then exported to Stata version 14 for analysis.

To assess the association between cholera cases and air temperature and precipitation, Poisson Regression and Zero-inflated negative binomial regression Models were used and compared to choose the best fit model. Zero-inflated negative binomial regression was the best fit model with (AIC 92.7, BIC 107.3) compared to the Poisson regression model with (AIC 296.5, BIC 303.8). The level of significance was set at less than 0.05 with a 95% confidence interval. Results were presented as frequencies in tables, percentages, and graphs. Data were restricted, and only the research team had access.

Ethical Considerations

The ethical approval of this research was obtained from the University of Zambia Biomedical Research Ethics Committee (UNZABREC). The researcher sought permission from Kapiri Mposhi District Local Authority and the District Health Office, which partly covers the Lukanga swamps where the study was conducted. The Fishing Committees in the Lukanga swamps were also informed of the study.

Results

Cholera Cases from 2010 to 2016 in Lukanga Swamps

The study revealed that there were 133 cholera cases in the period under study. It was observed that 2014 had the highest number of Cholera cases, whilst the lowest was in 2015, when 6 cases were recorded Figure 2.

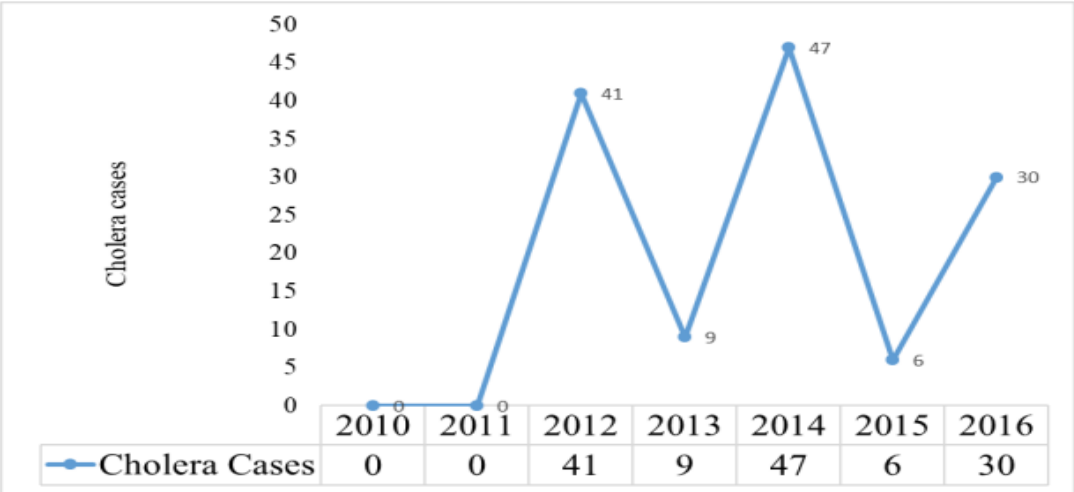


Figure 2. Cholera Cases in Lukanga Swamps from January 2010 to December 2016

Environmental Conditions (Precipitation and Temperature) in Lukanga Swamps from 2010 to 2016

The study revealed that air temperatures in the Lukanga Swamps ranged between 16°C and 28°C from January 2010 to December 2016, with the lowest temperature in June 2010 and the highest in October 2016. Monthly precipitation over the seven-year period showed high variability, spanning from 0.05 mm in April 2016 to 248 mm in December 2013 (Figure 3).

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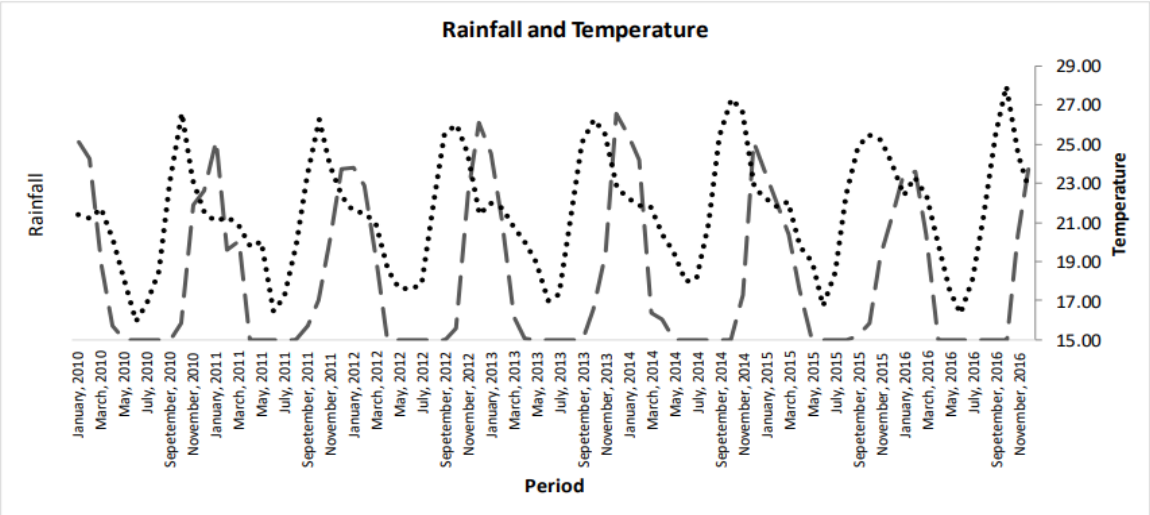


Figure 3. Rainfall (Dashed) and Temperature (Dotted) from 201 to 2016

Association between Environmental Conditions and Cholera Cases in Lukanga Swamps from 2010 to 2016

A significant association was found between increased temperatures and cholera cases (p = 0.001), while higher rainfall correlated with a reduced risk of cholera (IRR = 0.992, 95% CI: 0.988–0.997, p = 0.002). Additionally, cholera cases in the Lukanga Swamps occurred primarily during the dry season (Figure 4).

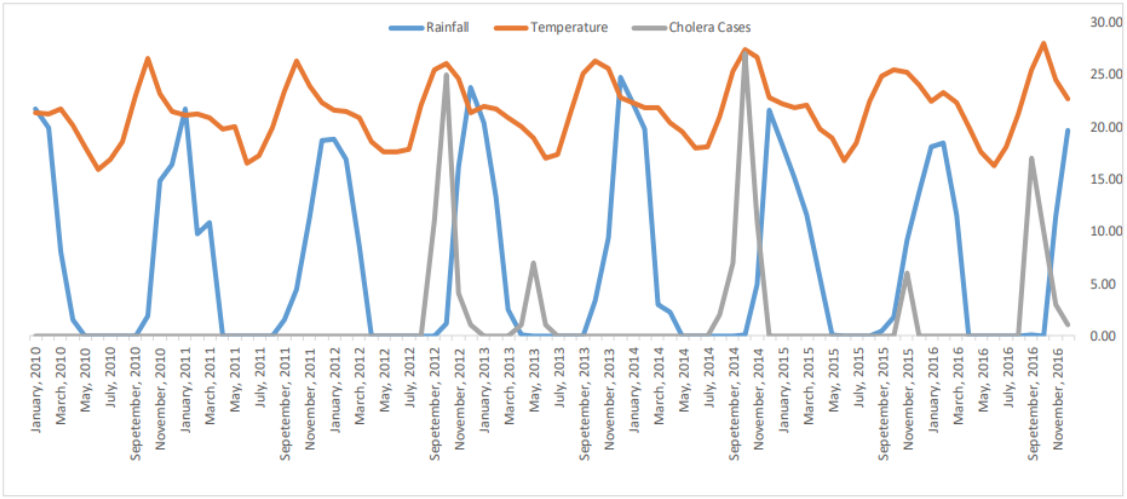


Figure 1. Association between Environmental Conditions (Rainfall and Temperature) and Cholera Cases in Lukanga Swamps from 2010 to 2016

Zero-Inflated Negative Binomial Regression Analysis of the Association between Temperature, Precipitation and Cholera Cases in Lukanga Swamps

The air temperature and rainfall data were collected over 84 months, and the study revealed that increased rainfall was associated with a decreased risk of cholera cases (Incidence RR = 0.992, 95% CI: 0.988–0.997, p = 0.002). The results also revealed that a 1-degree increase in temperature increased the risk of cholera cases by 27% and was statistically significant (IRR = 1.265, 95% CI: 1.142–1.402, p–value = 0.0001) (Table 1).

Table 1. Association between Rainfall, Temperature and Cholera Cases using Zero Inflated Negative Binomial Regression Analysis

Predictor Variable	Incidence Rate Ratio (IRR)	P-Value	[95% CI]
Temperature	1.265	0.0001	1.142 -1.402
Rainfall	0.992	0.002	0.988- 0.997
IRR = Incidence Rate Ratio, CI = Confidence Interval (N = 84 months)			

Sanitation Situation in 19 Lagoons of Lukanga Swamps from September 2017 to January 2018.

The study revealed that in Lukanga Swamps, there is no land that provides for digging and construction of sanitary facilities. That illustrates the impossibility of having a sanitary facility in that aquatic environment.

The study further revealed that people within the Swamps camps live on strong floating surfaces that had been naturally established, though reinforced with grass and reeds to strengthen the base. The study has also shown that both Fishermen and Fish Traders have specific areas designated for sanitation and also for drawing water for drinking, washing cooking utensils, and cooking within the same body of water.

Water Quality Monitoring from the 19 lagoons in Lukanga swamps

The water quality monitoring was conducted over two months, December 2017 and January 2018, to isolate faecal coliforms. The results of the monitoring showed that 19/36 (53%) of water samples were contaminated with faecal coliforms. In December 2017, 12/19 (63%) of the lagoons were contaminated, and the faecal coliform contamination level per 100 ml of water sample ranged from 1-200 Colony Forming Units (CFU). In January 2018, 7/19 (37%) of the lagoons were contaminated, and the faecal coliform contamination level ranged from 2-200 CFU, as indicated in Figure 5.

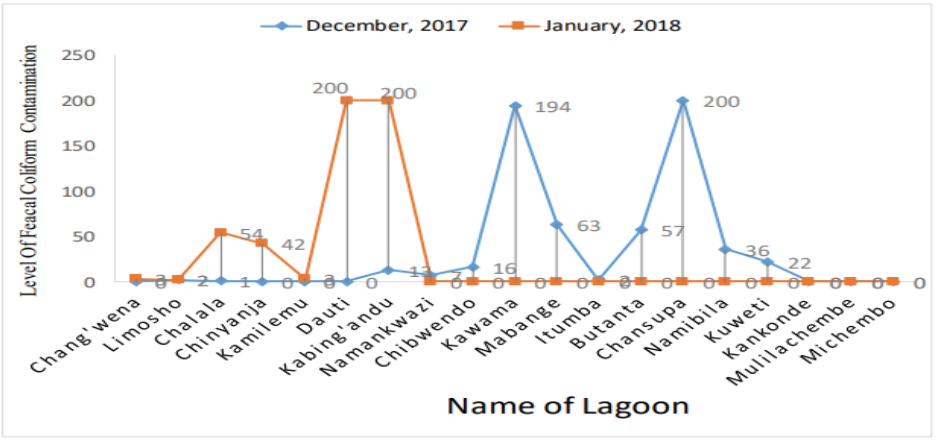


Figure 5. Faecal Coliform (FCU/200ml water) for December 2017 and January, 2018 per Lagoon

Microhabitat Condition (Water pH) of the 19 Lagoons in Lukanga Swamps

A total of 89 water samples were collected and tested for pH from 19 Lagoons monthly from September, 2017 to January, 2018. The pH in the lagoons under study ranged from 7.1 to 8.5. The study indicates that 2/19 lagoons (Chansupa and Chang'wena) gave pH readings more than 8.5 in all the months beyond the pH testing machine calibration range of 6.5–8.5, while other lagoons had some months with readings beyond the capacity of the testing machine. The study shows variants in pH readings from all 19 lagoons for the period of five months, Figure 6.

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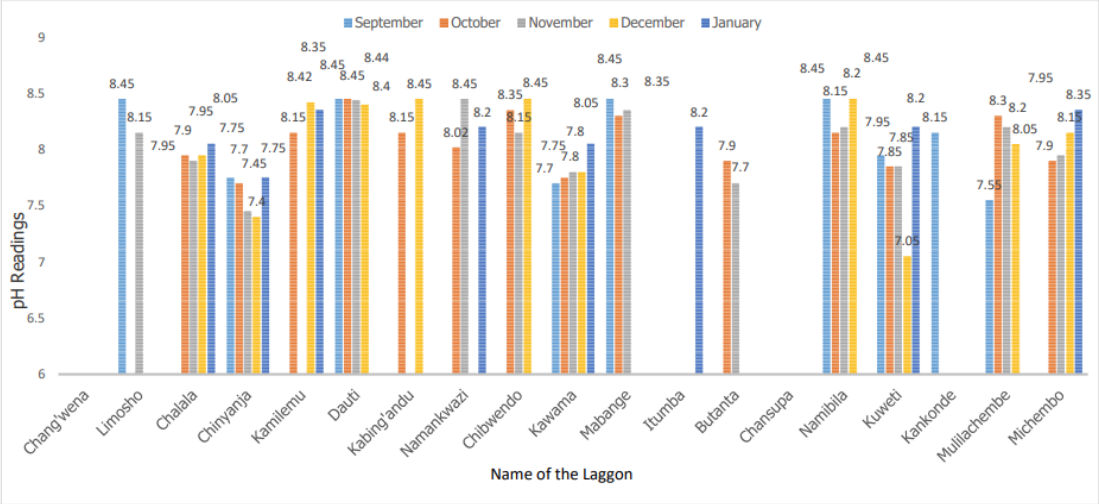


Figure 6. Monthly pH Levels in Water Per Lagoon from September 2017 to January 2018

Water Sample Analysis

A total of 164 water samples were analysed by two different Laboratories to isolate *Vibrio cholerae*. The study revealed that 90/90 (100%) water samples submitted to the Food and Drugs Control Laboratory to isolate Vibrio were all non-reactive. It further shows that of the 74/74 (100%) water samples submitted to the Centre for Infectious Diseases and Research in Zambia (CIDRZ) to isolate Vibrio were also non-reactive.

Discussion

A total of 133 cholera cases were recorded during the study period. The study indicates that precipitation and temperature are significantly associated with recurring cholera outbreaks in Lukanga Swamps. Environmental and microhabitat conditions provide a supportive environment for Vibrio to thrive and trigger cholera outbreaks within Lukanga Swamps. Water quality monitoring showed heavy contamination with faecal coliforms, ranging from 1-200 cfu/100 mL in water samples. The study also showed that all 164 water samples submitted to the Food and Drugs Control Laboratory (90) and the Centre for Infectious Disease and Research in Zambia (CIDRZ) (74), respectively, from September 2017 to January 2018 for Vibrio isolation were non-reactive.

This study revealed that cholera outbreaks mainly occurred during the dry season. This agrees with a study in Ghana on cholera outbreak response in two districts in 2016, which found that most cases occurred before the rainy season [11]. This contrasts with a study in Tanzania on co-variation of cholera with climatic and environmental parameters in coastal regions, which found that cholera cases occurred every month between 2004 and 2010 [12].

The study also found that one-degree increase in temperature increases the risk of cholera cases by 27%, and that was statistically significant. This agrees with the study done in Tanzania, which concluded that temperature was significantly associated with cholera, i.e., a 1- degree Celsius increase in air temperature increased the relative risk of cholera by 15–29% [13]. Water temperature, in particular, has been shown to be an important factor governing the seasonal and geographical variation in Vibrio cholerae [14]. Another study done in Tanzania shows a significant relationship between cholera cases and temperature and predicts an increase in the initial risk ratio for cholera in Tanzania in the range of 23-51% for a 1-degree Celsius increase in annual mean temperature [15]. The significant relationship between temperature and cholera cases could be because increased

temperature is supportive of growth and multiplication of Vibrio cholerae. A study conducted in China in 2012 shows that Vibrio is able to grow within the temperature range of 20oc and 45oc and that it cannot survive at 4oc for extended periods [16]. This finding is similar to the study of Gaudart and others, which revealed that about 50% or more cholera outbreaks occurred when the air temperature was > 31℃, approximately one standard deviation from average air temperature over the previous 2 months (solid line) [17].

On the other hand, according to a study done in India using a time series statistical model, the incidence of cholera has not been correlated with air temperature [18]. However, according to a time series analytical study done in Bangladesh, Ali and others hypothesised that an increase in Surface Sea Temperature (SST) results in replication of phytoplankton populations, which are directly associated with the increase in V. cholerae bacteria and are linked spatially and temporally to zooplankton populations [19].

This study has shown that increased rainfall was associated with decreased risk of cholera cases and was statistically significant. This may be linked to the occurrence of cholera outbreaks mostly during the dry seasons, with high peaks between August and October in Lukanga Swamps, and reduced cholera outbreaks during rainy seasons. This finding was consistent with a time series model study done in India for 11 years from 2000 to 2010, which showed initially that from 2000 to 2004, there was a significant association between rainfall and cholera cases, but from 2005 to 2010 the study indicated a significant negative association between rainfall and cholera cases [20]. On the other hand, a study done in Bangladesh showed an association between cholera and rainfall [21], and this finding was similar to a study done in Zambia byMudenda in 2014 that heavy rainfall and flooding were associated with triggering outbreaks of diarrhoea.

In this study, an assessment of sanitation status revealed that there was no land where to dig and construct sanitary facilities. A further assessment indicated that there was open defecation within the aquatic environment.

According to Juliana, the cholera organism can survive in almost all kinds of aquatic environments, including fresh water sources such as lakes, ponds, rivers and tanks. Cholera bacteria can also survive in non-aquatic environments such as refuse dump sites, fruits, fresh vegetables, meat, cooked food, human and animal faecal waste, untreated or inadequately treated waste [22]. The implication of open defecation in an aquatic environment would be a great contribution to the reservoir of V. cholerae. The challenge is that carriers could be asymptomatic and shed pathogenic clones in their stools, further enriching the water sources with virulent bacteria and facilitating the initiation of an epidemic [23]. A study undertaken in Ghana in two districts, Akatsi District in Volta Region and Komenda-Edina-Eguafo-Abirem (KEEA) Municipal in Central Region during the 2012 cholera epidemic provided a warning that Cholera remains a threat to areas where access to safe drinking water and adequate sanitation cannot be assured [11].

This study revealed that water sources in the Lukanga swamps were heavily contaminated. A water quality monitoring done in December, 2017 and January, 2018 indicated heavy water contamination with faecal coliforms ranging from 1 – 200 Colony Forming Units (cfu) /100ml of water samples, and that could be due to a cracked safe excreta disposal system and hygiene practices in the aquatic environment of Lukanga Swamps. These results have been substantiated by other studies, and a study conducted in the USA in 2011 indicated that substantial populations of fecal coliforms and E. coli are harbored in freshwater bottom sediments, bank soils, and

beach sands [24]. Another study in the USA revealed similar findings on assessment of the available wastewater treatment plant. Treated effluent data and in-stream sampling data indicated that water quality criteria for faecal coliform in recreational waters exceeded 800 cfu/100ml water samples at all locations of the Santa Cruz River [25].

The assessment of microhabitat condition, i.e., potential hydrogen (pH), showed variation across all 19 sampled lagoons over five months. The pH in 89 water samples collected and analysed to assess whether it was within the range that supported the thriving of V. cholerae ranged from 7.1 to above 8.5. These results align with previous studies, which have shown that a pH of ~8.0 and warm water temperatures between 19 and 28°C were associated with increased concentrations of cholera bacteria [17]. Another study conducted in Haiti to monitor water sources for environmental reservoirs of Toxigenic Vibrio cholerae O1 found that, because the sites varied from mountains to floodplains to estuaries, there was relatively wide variability in salinity (0–21.6 g/L), pH (6.4–8.6), and temperature (24.3–33.7°C) [26].

In this study, the analysis of water samples to isolate Vibrio cholerae from 19 sampled lagoons of the Lukanga Swamps from September, 2017 to January, 2018 did not yield positive results. A similar study revealed that in most cases Vibrio cholerae has been found to persist in its natural environment mainly in two forms: viable but not culturable (VBNC) and conditionally viable environmental cells (CVEC). VBNC is a dormant state that Vibrio cholerae enters in response to nutrient deprivation and other environmental conditions [23]. This could probably be one of the reasons isolation of Vibrio cholerae during the study period was not achieved. On the other hand, in a study done in Haiti, they managed to isolate Vibrio cholerae O1 (toxigenic and nontoxigenic), and all isolations occurred at water temperatures of >31°C. The study further indicated that there was evidence that Vibrio cholerae O1 isolation was more common in the environment preceding epidemic peaks of disease among humans [26]. Water samples were collected for analysis to isolate Vibrio cholerae during a non-epidemic period, making it relatively difficult to isolate the organism, as elucidated by Alam and others in their study.

Conclusion

The study revealed that there were 133 cholera cases in the period under study, with the highest number of cases recorded in 2014, with 47 cases, and no cases in 2010 and 2011, respectively. Air temperature was found to be the main predictor associated with cholera outbreaks in the Lukanga Swamps, and it shows the ability to predict these outbreaks with a lag time of two months prior to temperature rise. This implies that if temperature is monitored regularly and when it rises to levels that are supportive of a cholera outbreak, then disease preventive measures could be implemented to prevent the outbreak. The study also revealed that increased amount of rainfall was associated with decreased risk of cholera cases. In Lukanga Swamps, therefore, increased amount of rainfall plays a preventive role against cholera outbreaks, and the risk of cholera outbreaks increases when there is reduced amount of rainfall. This is very important for policy makers and implementers to note when it comes to the application of interventions to prevent disease outbreaks in Lukanga Swamps.Microhabitat condition (pH) showed a supportive environment for growth of Vibrio cholerae within the Lukanga Swamps, and coupled with poor sanitation, the risk of cholera outbreak increases. Environmental factors therefore provide early warning systems of cholera outbreaks for impactful implementation of identified interventions in that aquatic environment. Environmental factor-based interventions, coupled with disease

surveillance and individual vaccination, should be fundamental elements for preventing and controlling cholera outbreaks in the Lukanga Swamps.

Recommendations

- To develop an Environmental Management policy that will address environmental factors associated with cholera outbreaks in Fishing Camps of Lukanga Swamps.
- Establishment of a robust surveillance system to detect trend variations in environmental factors and conditions that trigger cholera outbreaks in Lukanga Swamps.
- Development of an individual cholera vaccination programme in Fishing Camps for cholera-prone areas.
- Promote safe water and hygiene within the Lukanga Swamps.
- Strengthen and conduct regular monitoring of environmental factors associated with cholera outbreaks in that aquatic environment.
- Develop and implement an epidemic preparedness plan for mounting a timely and appropriate response.

Limitations of the Study

Humidity could not be extracted through remote sensing, which was supposed to be assessed alongside temperature and precipitation, because it required more time to process.

Water quality monitoring to isolate fecal coliforms was conducted for only two months, December 2017 and January 2018, due to inadequate funds for analysis. Some potential confounding variables that were not identified or considered during the study, and that future studies should consider, include: population movement, water use behavior, vaccination, and socioeconomic status.

What is already known about this Topic?

- Cholera is an epidemic and endemic disease in certain areas
- That Environmental Factors can be associated to cholera endemicity in Lukanga Swamps

What this study adds

- This study shows that air temperature was the main predictor associated with cholera outbreaks in the Lukanga Swamps, and it demonstrates the ability to predict these outbreaks with a lag time of two months prior to a temperature rise.
- This implies that with regular temperature monitoring, preventive measures could be implemented to prevent the outbreak at the right time.
- The study also revealed that an increased amount of rainfall was associated with decreased risk of cholera cases. In Lukanga Swamps, therefore, increased amount of rainfall plays a preventive role against cholera outbreaks, and the risk of cholera outbreaks increases when there is reduced amount of rainfall.

Competing Interests

The authors declare no competing interests.

Acknowledgments

I am deeply indebted to my supervisors from the University of Zambia (UNZA), School of Public Health, and from CIDRZ for their guidance and constructive criticism. My gratitude goes to my mentors, Dr. Cleopatra Chisenga from CIDRZ and John Mwaba from the University Teaching Hospital, for providing technical support to me. Further, I wish to thank CIDRZ, which supported me financially to achieve this work. I also render my humble gratitude to the National Remote Sensing Centre for the technical guidance on ArcMap and ArcGIS software to extract the Environmental data from Lukanga Swamps.

Lastly, I appreciate all my workmates at Kapiri Mposhi District Health Office, without whose support and cooperation the study could not have been a success.

Authors' Contributions

- **Simeon Sikwiiya:** Conception and design, acquisition of data, analysis and data interpretation, critical revision and manuscript writing.
- **Meki Deborah Chisala, Roma Chilengi:** Conception and design, supervision, critical revision, funding acquisition, and manuscript writing reviews and final approval.

Data Availability

The data supporting this study are not publicly available due to privacy restrictions and ethical concerns. Still, they are available from the corresponding author upon reasonable request and with permission from the National Remote Sensing Centre of Zambia, which provided technical support to extract the climatological data through the Remote Sensing System.

Funding

This research work was partially supported by CIDRZ, which specifically supported the collection of Water samples for five months to assess the presence of Faecal Coliforms, *Vibrio cholerae,* and to determine the Potential Hydrogen Levels. The funding support was from the Epidemic Preparedness and Response grant rendered to Kapiri Mposhi District Health Office aimed at addressing the endemic cholera in the Lukanga Swamps.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art010

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Governance and Implementation Gaps in Adolescent Sexual and Reproductive Health Education and Services: Perspectives of Adolescent Girls and Policy Implementers in Tiko Health District, Southwest Cameroon

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Cite this article as: Binsila Bernard Benjika, Nana Celestin, Bodzewan E.F. Governance and Implementation Gaps in Adolescent Sexual and Reproductive Health Education and Services: Perspectives of Adolescent Girls and Policy Implementers in Tiko Health District, Southwest Cameroon. Texila Int J Acad Res. 2026;13(4). https://doi.org/10.21522/TIJAR.2014.13.04.Art010

Received: 18.08.2026

Accepted: 25.09.2026

Published: 30.10.2026

Article Type: Original Research

Abstract *The strive toward achieving adolescent girls' sexual and reproductive health empowerment (SRHE) cannot be without challenges. The study examined governance and implementation gaps in establishing effective operational mechanisms that enhance and sustain adolescent girls' SRHE. The study obtained ethical approval and used a concurrent triangulation and sequential exploratory mixed-methods design, combining quantitative and qualitative approaches within a survey framework. A total of 395 participants took part in the study, comprising 384 adolescent girls and 11 key informants from the traditional, educational, health, social, legal, women and gender empowerment, and NGO's sectors. We analyzed quantitative data using SPSS, while we conducted thematic analysis of qualitative data using ATLAS.ti and NVivo. The findings revealed breaches in adolescent girls' SRHE, ranging from early indulgent sex, transactional sex, unintended pregnancy, school dropout, unsafe abortion, and low perception of contraceptives, with a preference for condoms. Although the socio-political crisis contributed through poverty, displacement, and family disruption, other salient facilitators included inadequate policies and governance, with the education sector still lacking structure and specificity. To improve and sustain adolescent girls' SRHE, stakeholders suggested the refinement of SRH education, notably in secondary school, and the proper structuring and implementation of policies in a multi-sectoral approach while striving to end the socio-political crisis, alleviating poverty and fostering early home-based education, comprehensive / intensified school-based education with effective integration into the curriculum, intensified community-based education and awareness, and controlled information through mass and social media, while intensifying education from early adolescence. The T-SAG-SRHE Model (Tiko–Sexual and Reproductive Health Empowerment of Adolescent Girls Model) is introduced as a context-responsive framework designed to address policy and implementation gaps in adolescent sexual and reproductive health education and services within the Tiko Health District and comparable contexts*

Keywords *Adolescent Girl, Cameroon, Empowerment, Grounded Theory, Pathway, Resource-Constrained Setting, SRH, Southwest.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art010

Introduction

Adolescence is a period of physical, social, and psychological development for individuals aged 10-19 years [1, 2]. Adolescence falls within the third and the fifth social stage. The third social stage is childhood, characterized by social apprenticeship and novice status in the social ontogenetic stage, whereby the developmental tasks embody recognizing and cognizing social rules, acknowledging self in connectedness, peer group interaction, and work; the fourth social stage is puberty, characterized by social entrée in the social ontogenetic stage, whereby the developmental tasks include recognizing and adjusting to change, performing domestic chores/duties, and participating in rites of passage, if any. The fifth social stage is adolescence, characterized by probation and socialized internship, with developmental tasks including visualizing the self, completing passage training, being poised for adult roles, and serving as a junior partner, as a proto-adult with a high risk of teenage motherhood. The sixth stage, which ends adolescence, is adulthood, with developmental tasks of marriage, responsible parenthood, and productivity /societal reproduction [3]. Adolescence is a time of comprehensive and profound change, including puberty and the development of physical, cognitive, and social maturity [4]. In girls, this period as a specific stage of life requires special attention and consideration [5] because the beginning of adolescence is associated, on the one hand, with the onset of puberty and menstruation and, on the other hand, with the discovery of sexual desires [6, 7]. Misconceptions and wrong health behaviors in the process of menstruation and puberty endanger the health of girls [8].

Moreover, due to the discovery of sexual desires, involvement in high-risk sexual behaviors might occur for many adolescent girls and lead to sexual intercourse, unwanted pregnancy, or sexually transmitted diseases. In Sub-Saharan Africa, adolescents make up a significant share of the global population, accounting for about 23 percent [9]. Adolescence is a critical age in which people undergo multifaceted sexual development [10]. Sundry health risks and complications secondary to unprotected sexual activity among adolescents have been reported and documented by the World Health Organization [11, 12], for which urgent and prompt interventions are recommended. Recent data indicate that 1.2 billion people worldwide are adolescents aged 10-19 years [13]. Adolescents are slightly at an increased level of vulnerability for different health conditions, including sexually transmitted diseases, when compared to the adult population [14]. Risky sexual behavior is characterized by different hazardous behaviors ranging from premarital sex, multiple sexual partners, to unprotected sex. Such hazardous sexual behaviors are reported to end up with unpleasant health outcomes like HIV/AIDS, unwanted pregnancies, unsafe abortions [15], and other STIs. The program of action adopted at the International Conference on Population and Development (ICPD) in Cairo in 1994 stimulated considerable interest among international agencies, governments, Non-Governmental Organizations, and donors in formulating policies and programs to meet the needs of adolescents in developing countries and protect their rights. Among other recommendations, the Cairo agreement urged governments to provide adolescent girls and boys with the necessary sexual and reproductive health information and services to enable them to deal in a “positive and responsible way” with their sexuality [16]. To support this initiative, the World Health Organization (WHO) developed criteria and standards for implementation in all health care settings that serve young people. Most importantly, Adolescent and Youth Sexual and Reproductive Health and Rights (AYSRHR) services should be accessible, acceptable, equitable, appropriate, and effective [17].

Young people's participation in developing, implementing, evaluating, and advocating for AYSRHR interventions improves their effectiveness [17], so programs should integrate them at different levels and give this participatory approach sufficient attention.

Legal and regulatory policies across governance sectors have integrated aspects of SRH, but in most cases, this is more like patching than structured integration. Similar disparities exist in other conventions and regulations. For instance, although Cameroon is a signatory to the 1989 United Nations Convention on the Rights of the Child, which sets the minimum age for marriage at 18 years, Cameroon's civil code permits girls to marry at 15 years with parental permission and boys at 18 years. However, the country is adopting new procedures to end this harmful traditional practice. It is against this backdrop that Cameroon's new penal code, enacted as law in July 2016, in its section 356, sanctions anyone who compels another to marry before 18 with imprisonment from 5 to 10 years and a fine from 25.000 to 1.000.000 FCFA. Meanwhile, the lack of denunciation prevents assessment of the effectiveness and efficacy of such a measure [9]. Sexual exploitation and abuse violate human rights and are a betrayal of the core values of the United Nations [18]. These rights and any form of discrimination against women are also emphasized in the Protocol to the African Charter on Human and Peoples' Rights on the Rights of Women in Africa [19] as adopted in Maputo and by the Penal Code of Cameroon (Ministère de la Promotion de la Femme et de la Famille, 2024). Besides this, several other legal or institutional frameworks protect the rights of young girls and help guide their empowerment toward safe sexual and reproductive lives in Cameroon, as depicted Ref. [20]: Article 5 of Law No. 98/004 on the Direction of Education in Cameroon (1998) includes, among its objectives, family education and the promotion of hygiene and health education. In 2007, Cameroon made an inter-ministerial decision to introduce family life education, population education, and HIV/AIDS prevention into the curricula. However, no specific legislation recognizes a right to Integrated Sexuality Education (CSE).

Updated in 2009, the 2001-2015 Health Sector Strategy defines national health policy and identifies strategic areas to improve young people's sexual and reproductive lives. Family planning is one of the intervention categories included in the mother and adolescent health sections. The adolescent health component includes the prevention of early and unwanted pregnancies, the prevention of STIs and HIV, and the establishment of reproductive health services adapted to the needs of young people. However, the SRH components are not specifically structured, and their interconnectedness is not established to support comprehensive action and intervention. The 2009 National Youth Policy proposes reducing maternal mortality among young people and, as one initiative, improving family life education. However, it does not extensively address the precursors, response measures, or the interconnections among interventional sectors and stakeholders. As if acting independently, without a structural description of precursors in a sector-based approach and in a proactive enforcement perspective, the Reproductive Health Services Policy (2009) includes a section on the health of adolescents and young people, the objectives of which are: the prevention and management of diseases, dysfunctions related to their sexuality, the reduction of morbidity and mortality rates linked in particular to unwanted pregnancies, early maternity, induced abortions, STIs and HIV & AIDS, and a focus on education on family life and sexuality.

In the same vein, the Protocol to the African Charter on Human and Peoples' Rights on the Rights of Women in Africa (African Union, 2003) protects the reproductive rights of women by authorizing medical abortion in cases of sexual assault, rape, incest, and where

the continued pregnancy endangers the mental and physical health of the mother or the life of the mother or the fetus. International, regional, and national human rights bodies and courts increasingly recommend decriminalization of abortion and provision of abortion care to protect a woman's life and health, and in cases of rape, based on a woman's complaint. Some argue that ensuring that laws, even when restrictive, are interpreted and implemented to promote and protect women's health is essential [21]. Unsafe abortion accounts for 13% of maternal deaths, and 20% of the total mortality and disability burden due to pregnancy and childbirth [22]. Almost all deaths and morbidity from unsafe abortion occur in countries where abortion is severely restricted in law and in practice [21]. The National Reproductive Health Program's Strategic Plan (2009) identifies obstacles to implementing the program. These are mainly socio-cultural barriers, the low use of family planning services by young people, the non-existence of structures adapted to their needs, and low levels of contraceptive use. However, the plan highlights the existence of non-governmental organizations or associations working with reproductive health issues of young people, the inclusion of courses on sexuality education in school programs, and the integration of the adolescent health component into the priority programs of the health sector; though globally these actions remain institutionally patchy, without offering a structured multi-sectoral approach to prevention and intervention.

The 100% jeunes' program, which started in 2000, targets young people aged 15-24, aiming to encourage them to adopt responsible sexual behaviors, such as the use of male condoms. Peer educators of the same age have been integrated into information, education, and communication activities. The media also play an important role in awareness, prevention, and promotion activities, but the arena is chaotic. The National Strategic Plan for the Fight Against HIV, AIDS and STIs (2018-2022) states that the ministries in charge of education will be responsible for integrating information and education on HIV & AIDS into curricula for training students at all levels, as well as interventions for teachers. In 2013, the government mandated that teachers incorporate some form of HIV sensitization into their lesson plans, regardless of the subject they taught. Still, the question now is how comprehensive and structured this is. The 2006 Pedagogical Guide for Family Life Education for primary and secondary education outlines teaching methods and recommendations for addressing Family Life curriculum topics, subdivided into several themes. Similarly, the 2018 primary education curriculum includes learning units on topics such as reproductive health, health education, the human reproductive system, HIV & AIDS, family planning, puberty, and menstrual hygiene. However, it still does not provide a specific framework for where these topics should fit within the curriculum.

The Southwest region, as of December 2023, has 41912 estimated number of people living with HIV (SPECTRUM; a statistical software used by the National AIDs Control Committee). This is coupled with the socio-political crisis in the region, which has brought in a lot of internally displaced persons (IDPs) and has also led to high sexual promiscuity, exposing adolescent girls to a high risk of HIV/AIDS and other STIs. The pathway of adolescent girls to sexual and reproductive health (SRH) empowerment in many sub-Saharan African countries is not without a myriad of hurdles. Still, the main hurdles remain governance and policy. Despite its illegality in Cameroon, induced abortion is still practiced, whereas this is prohibited by the Reproductive Health Services Policy (2009). In 2015, in the obstetrics and gynecologic services in Yaounde, Cameroon, the prevalence of voluntary induced abortion was 26.3% (134/509) globally; 25.6% (65/254) in urban areas and 27.1% (69/255) in rural areas, with excessive bleeding as the main risk [23]. It was

reported that unsafe abortion accounts for 13% of maternal deaths [1], and 20% of the total mortality and disability burden due to pregnancy and childbirth [22]. An early study in Tiko Health District revealed that having multiple sexual partners was a risk factor for the prevalence of teenage pregnancy and further cautioned that a good number of them lack adequate knowledge of comprehensive sexuality education [24], thus posing a major question about the effectiveness of their sexual and reproductive health empowerment.

Study Objective

The study examined governance and implementation gaps in establishing an effective operational mechanism to enhance and sustain adolescent girls' SRHE.

Materials and Methods

Research Design

This study employed a survey design and, more specifically, a concurrent triangulation mixed-methods approach that combined quantitative and qualitative methods and gathered data from different stakeholders in the initial phase. This design collected qualitative and quantitative data concurrently through a survey process to strengthen the validity of the findings. The second phase followed a sequential exploratory mixed-method design in which, based on trends in the initial findings, the researchers developed an interview guide to capture key informants' general perceptions of the subject matter, including strengths and weaknesses. The quantitative component focused essentially on adolescent girls. For the qualitative component, the study targeted key informants because they are involved not only in policy implementation but also, to some extent, in its conception and development.

Study Area and Setting

The study was conducted in the Tiko Health District, located in the Fako Division of the Southwest Region of Cameroon. The district comprises nine health areas and approximately 94 communities, with an estimated population of 104,224 following the 2021 population census [25]. The district delivers health services through a decentralized health system involving district health authorities, health facilities, and community-based health workers (CHWs) who implement CDI (Community-Directed Interventions). Since 2016, the region has experienced a socio-political crisis that poses enormous challenges to implementing frontline health programs and has significantly contracted the economy [26]. Disruption and insecurity have also affected the financial sector, and employment has dropped because of persistent violence and the sharp collapse of major economic sectors and social fabrics [26].

Study Population and Sampling

The study population included adolescents, household heads, educators, health personnel, and policymakers from various sectors in the Tiko Health District, Southwest Region, Cameroon. Adolescents are central to the study. Still, the individual determinants of their sexual and reproductive life are highly influenced by the other participants included in the study, which contributes to shaping their psychological and socio-economic development. For the quantitative component, we determined a minimum sample size of 410 adolescent girls using the single-population proportion formula, assuming a 95% confidence level, a 5% margin of error, and a prevalence of 50%. For the qualitative component, we purposively and conveniently sampled 15 key informants from the diversified sectors described earlier. We selected health areas and communities through simple random sampling to ensure geographical representation across the district. We conveniently sampled adolescent girls in communities, and those aged below 16 years were at home with parental consent, as required. For the qualitative study, we purposively and conveniently sampled participants.

Data Collection Tools and Procedures

Researchers used a semi-structured questionnaire to collect information from active adolescent girls through a face-to-face approach, after administering the assent form to those aged 16 years and above and the consent form to the parents of those below 16 years. The information included the demographic characteristics, the home environment (socio-economic status, parenting style, support, norms, physical, lifestyle), physical environment and lifestyle, school environment, community and socio-cultural norms, health system (accessibility, youth-friendly services, provider attitudes), legal and policy environment (rights, protection frameworks), conflict and fragility context (Southwest Cameroon crisis), individual mediators, and empowerment dimensions as predictors of sexual and reproductive empowerment, which on its own is appraised under the section labeled SRH empowerment outcomes. The last section consisted of prospects and contraceptives, which is structured in the form of open-ended questions to capture adolescent girls' perceptions of the risks of unsafe sexual life and their suggestions to reduce them. As for the key informants, an interview guide was used.

Validity of Data Collection Instruments

The researchers ensured the validity of the data collection instruments through content, construct, and face validity procedures. A public health research supervisor and a statistician reviewed the instruments to assess clarity, relevance, and alignment with the study objectives. We conducted a pilot study in Molyko and Mile 16 health areas in Buea Health District, which were not included in the final sample, to test comprehensibility, feasibility, and contextual appropriateness. Feedback from the pilot informed refinements to the instruments' wording, response categories, and data collection procedures.

Reliability of Data Collection Instruments

We assessed the internal consistency of the quantitative instrument using Cronbach's alpha coefficient. The reliability coefficients ranged from 0.777 to 0.963, indicating acceptable to excellent internal consistency for adolescent girls. For qualitative tools, expert review using the parallel method and pilot testing enhanced reliability by ensuring clarity and consistent interpretation of questions. We standardized and cross-checked data collection procedures to minimize measurement errors.

Ethical Considerations

The Ethics Committee of the Regional Delegation of Public Health for the Southwest Region granted ethical approval, and the Regional Delegate of Public Health granted administrative authorization, with support from Texila American University. Participants were informed about the study's purpose and procedures before data collection. Participation was voluntary, and respondents could decline or withdraw at any time without negative consequences. All participants provided informed consent before interviews and questionnaire administration. We maintained confidentiality and anonymity by not recording personal identifiers; all collected information was backed up, used strictly for research purposes, and reported in summary form.

Data Analysis

Data from adolescent girls' surveys were collected electronically using tablet devices running the Kobo Collect platform. The electronic tools included skip patterns, validation rules, and range checks to reduce entry errors. The team uploaded completed questionnaires daily to a secure, password-protected server and backed them up regularly. The field supervisor and statistician reviewed submitted forms each day to identify missing data or inconsistencies and ensure data quality. The team audio-recorded key informant

interviews with participants' consent, transcribed them verbatim, and translated them into English where necessary. The research team stored all transcripts and field notes in encrypted folders accessible only to the team. The team analyzed quantitative data using IBM SPSS Statistics version 27. We used descriptive statistics, including frequencies, percentages, means, and standard deviations, to summarize adolescent girls' perceptions. Multiple-response analysis was conducted where applicable. We identified critical predictors of empowerment using Binary and Multinomial Logistic Regression, preceded by bivariate analysis with the Chi-Square test to identify significant associations with the dependent variable. We abstracted qualitative data through thematic analysis using ATLAS.ti and NVivo. Codes were generated from the transcripts and grouped into broader themes, with illustrative quotations and summaries grounded in code-quotation tables following the positivism paradigm, used to complement the quantitative findings and support interpretation.

Results

Socio-demographic Characteristics

A total of 395 participants took part in the study: 384 adolescent girls and 11 key informants. For the adolescent girls, the return rate was 93.7%, and challenges of working in remote areas in this socio-political crisis context contributed to this. For key informants, the return rate was 73.3%, and some felt embarrassed about discussing policy issues related to adolescent SRHE. The overall return rate was 93.8%. Adolescent girls and key informants were well stratified by demographic characteristics, which supported the representativeness and validity of the data (Table 1).

Table 1. Socio-Demographic Characteristics of Adolescent Girls

Variable	Category	n	%
Adolescent girls (N = 384)			
Type of locality	Urban	313	81.5
	Rural	71	18.5
Age	10–15	191	49.7
	16–19	193	50.3
Age of primary partner	15–19	61	15.9
	20–29	121	31.5
	30–35	8	2.1
	Not yet	194	50.5
Source of financial support	Self	78	20.3
	Parent/guardian	213	55.5
	Romantic partner	93	24.2
Employment status	No employment	281	73.2
	Formal sector employment	32	8.3
	Informal sector employment	71	18.5
Age at sexual debut	12–15	39	10.2
	16–19	130	33.8
	Not yet	215	56.0
Number of children	0	279	72.7

	1	91	23.7
	2	14	3.6
Marital status	Married	37	9.6
	Single	293	76.3
	Engaged	54	14.1
Religion	Traditional religions	16	4.2
	Christianity	317	82.5
	Islam	30	7.8
	Do not believe	21	5.5
Person primarily in charge of Sexual and reproductive education of the girl child in the family	Father	66	17.2
	Mother	147	38.3
	Both	171	44.5
Parents are alive	Dead	67	17.4
	Alive	317	82.6
Person with whom currently living	Father and mother	152	39.6
	My father	29	7.6
	My mother	45	11.7
	My uncle/aunt/other relative	22	5.7
	Family friend	14	3.6
	Alone	122	31.8
Principal occupation of parents/guardian	Unskilled / semi-skilled worker	284	74.0
	Skilled worker	100	26.0
Highest level of school attained by parent/guardian	Never been to school through primary	76	19.8
	Secondary and high school	127	33.1
	Post-secondary and university	181	47.1
Perceived status of family	Poor	55	14.3
	Average	294	76.6
	Rich	35	9.1
Key informants (N = 11)			
Sex	Male	6	54.5
	Female	5	45.5
Age group	16–24 years	0	0.0
	25–54 years	10	90.9
	55–64 years	1	9.1

	≥65 years	0	0.0
Level of education	None	0	0.0
	Primary	0	0.0
	Secondary	1	9.1
	Tertiary/University	10	90.9

Adolescent Girls

The distribution of adolescent girls' sample portrayed satisfactory stratification. By locality, urban dwellers were more represented (81.5%), reflecting their larger share of the population, as people mostly fled rural areas to urban areas because of the ongoing socio-political crisis. By age, they were almost equally split between 10-15 and 16-19 years. Almost half of them already had a partner (49.5%). Regarding their source of finance, they were vulnerable: 20.3% relied on themselves and 24.2% on romantic partners, which may have been magnified by their employment status, as most were not employed (73.2%). A good share of them already had sex (44%), with 10.2% falling between 12-15 years. Overall, 27.3% already had children, whereby 12.6% of those aged 10-15 years had a child. Of the adolescent girls, 9.6% (37) were married. In comparison, 14.1% (54) were engaged, and cumulatively 5.2% (10) of the younger ones (10-15 years) were married or engaged, as against 42.0% (81) for the older ones (16-19 years), thus highlighting the risk of early marriage in the study context coupled with early sex previously depicted. As for who primarily handles sexual and reproductive education for the girl child in the family, adolescent girls named both mother and father 44.5% (171), followed by mother 38.3% (147), then father 17.2% (66), alleging the efficacy of a two-parent home. When layered with setting type, fathers intervened more in urban areas, while mothers did so more in rural areas. Almost 17.3% had their parents dead, while only 39.6% were living with both parents, which could enhance their vulnerability. Parents were mostly unskilled / semi-skilled workers (74.0%), and their home/family status was mostly scaled as average (76.6%). A significant number of parents (19.8%) had never attended school or had only primary education (Table 1).

Key Informants

Key informants came from diverse offices and institutions, including the regional delegation of public health, chiefdoms, the court or legal system, NGOs, the church, the delegation of social affairs, and the inspectorate of education. They included reproductive health focal points, regional communication focal points, wise women, religious leaders, male traditional leaders, lawyers, NGO coordinators of SRH-related programs, focal persons for reproductive health, and the chief of the Bureau of Pedagogy. They were almost equally shared between males and females. All attained University level, with only one having A-level, indicating a relatively high level of education. Their ages ranged from 30 to 58 years, with most over 40, indicating seniority and substantial life experience and exposure. They also had experience in their area of intervention, with most having 5 years or more. These diversifications in profile, specialization, office, and area of competence, coupled with relatively high life and professional experience, added value to the quality and representativeness of the information (Table 1).

https://doi.org/10.21522/TIJAR.2014.13.04.Art010

Addressing Gaps in Governance and Implementation of Adolescent Girls' SRH Empowerment

Major Sexual and Reproductive Health Challenges Affecting Adolescent Girls

Table 2. Major Sexual and Reproductive Health Challenges Affecting Adolescent Girls

Indicators	Adolescents (N = 384)	Stakeholders (N = 11)	χ2-test (P-value)	Evidence
Current state of sexual and reproductive health empowerment among adolescent girls is satisfactory	91.2	27.3	0.000	Quantitative Vs Qualitative
Risk of teenage pregnancy	28.6	45.5	0.227	
Risk of school dropout	80.7	72.7	0.510	
Risk of sexually transmitted infections (HIV and other STIs)	70.8	54.6	0.247	
Risk of unsafe abortion	0.0	36.4	0.000	
Risk of gender-based violence (Sexual abuse, rape)	40.9	36.4	0.780	
Risk of child marriage	8.3	27.3	0.029	
Risk of transactional sex	20.3	45.5	0.043	
Risk of menstrual health challenges	-	36.4		Qualitative
Mental health problems/stress and anxiety	12.7	36.4	0.022	Quantitative Vs Qualitative
Awareness of contraceptive	81.8	72.7	0.444	
Willingness to use contraceptives	49.7	45.5	0.789	
Condom as preferred or recommended contraceptive methods	79.6	27.3	0.000	

There was a high discrepancy between adolescent girls' and key informants' perceptions with respect to major sexual and reproductive health challenges affecting adolescent girls. For instance, if adolescent girls generally perceived their current state of sexual and reproductive health empowerment as satisfactory (91.2%), this proportion dropped significantly to 27.3% among key informants. Only key informants highlighted the risk of unsafe abortion, and adolescent girls were unaware of the risk associated with inadequate menstrual hygiene, or maybe they did not perceive it as a priority issue. Condoms were preferred, and adolescent girls highly indicated them as the recommended contraceptive method, while this was not the case with key informants, who advocated for a diversified range of contraceptives. Both categories of stakeholders acknowledged that though adolescent girls were aware of contraceptives, their willingness to use them was low. They also both agreed on the risk of sexually transmitted infections (HIV and other STIs). However, key informants highlighted the risk of school dropout, and this trend was the same with transactional sex perceived as more critical by key informants, as well as the risk of early marriage and mental health problems (Table 2). Besides teenage pregnancy, poverty also contributed to the under-schooling of adolescent girls: *"Lack of means to be educated" (Female health care manager)*. The groups of girls that were mostly vulnerable were out-of-school girls, internally displaced girls, girls with disabilities, rural girls, orphans, girls living in poverty, younger ones, and lazy ones. "*The younger ones, for instance, should*

not be sent to hawking, and laziness makes older ones more exposed to selling their body" *(Male Traditional leader)*. Key informants argued that factors that foster unsafe abortion were fear of parents and the need to further education *"School continuation concern" (Female social affairs counselor)*, unintended pregnancy, stigma, poverty / financial constraints, limited contraceptive access, inadequate parental care, peer influence, and the business around it, as it was perceived as a source of money for health practitioners *"Yes, because there are so many cases, and they mostly advise girls toward that direction because they want to make money; they want to sell their drugs" (Urban male parent)*.

sUnsafe abortion was a major concern, as key informants were alarmed by the risk of infection, menstrual disorders, and excessive bleeding. They argued that unsafe abortion could be reduced through the creation of an independent center for adolescents and that abortion should not be encouraged. Measures should be put in place to frustrate abortion and encourage abstinence, protected sex before marriage, faithfulness in couples, and teaching them more about their sexuality and menstrual cycle. Community education and sensitization should be prioritized, alongside campaigns to distribute condoms and place girls on contraceptives. The risk of sexual violence was obvious *"Girls are sexually violated; they have been raped" (Female health care manager)*. In a nutshell, forms of violence affecting adolescent girls ranged from sexual violence, rape, emotional abuse, coercion, intimate partner violence, and economic violence. Main drivers of adolescent pregnancy in the district were poverty, knowledge deficit, peer pressure, school dropout, and substance abuse like drugs. Factors contributing to HIV and STI transmission among adolescent girls were generally similar to the factors driving adolescent pregnancy, though emphasis here was placed on inadequate education and poverty. Consequences adolescent pregnancies have on girls' lives were school dropout, traumatization, low self-esteem or frustration, hindered economic opportunities, and exposure to risks related to abortion that can even lead to death, as emphasized by this quotation: *"Risks of abortion, they can die" (Female health care manager)*.

Home and Family Environment

Table 3. Home and Family Environment as Barriers to SRHE of Adolescent Girls

Indicator	Barriers		χ^2-test (P-value)	Evidence type	Quotations
	Adolescents	Stakeholders			
Parenting style	44.3	63.6	0.205	Quantitative Vs Qualitative	*"The factors that drive them to do unsafe abortion are fear of parents" (Female social affairs counselor)*
Cultural taboo and religious belief	26.1	63.6	0.078		*"That cultural belief and some religious denominations that compel the Christians not to do this, not to do that. For them, for a girl to be pregnant is quite a taboo, and this can expose them to unsafe abortion, so those are some of the barriers" (Pedagogic inspector, basic education)*

Parents' lack of knowledge	16.7	63.6	0.000		*"Increasing sensitization in the community" (Female health care manager)*
Parents' fear of embarrassment	50.3	45.5	0.754		*"At times when the child does something wrong, they cover" (Female social affairs counselor)*
Time constraints	16.7	27.3	0.357		*"Parents could be too busy" (male traditional leader).*
Inadequate proactiveness	-	36.4		Qualitative	*"Poor prevention " (male pastor)*
Inadequate communication and education	-	27.3		Qualitative	*"So, we are not yet at the level where we can freely communicate those things with our daughters. So, we find it very uncomfortable talking about sex with our children" (Pedagogic inspector, basic education)*

Parenting style, cultural taboo and religious beliefs, lack of knowledge, fear of embarrassment, time constraints, inadequate proactive communication and education were barriers inherent to the home and family environment (Table 3). Key informants stressed the need for parents to open up to their adolescent girls and tell them the truth instead of hiding it: *"I think parents should tell them the truth instead of hiding it" (Female health care manager)*. Inadequate parenting was more pronounced in separated homes and homes where parents were dead *"Especially separate home girls because the mother is somewhere, the father is somewhere, they are having pressure to get money to take care of themselves" (Female social affairs counselor)*. *"Dead parents: I have had a situation where the boy in question and the girl, their parents were all dead" (Female social affairs counselor).*

School Environment

Table 4. School Environment as Barrier to SRHE of Adolescent Girls

Indicator	**Barriers**		**χ2-test (P-value)**	**Evidence type**	**Quotations**
	Adolescents	**Stakeholders**			
Risk of school dropout / under-schooling	21.5	27.3	0.646	Quantitative Vs Qualitative	*"Most of them end up as dropouts" (Female health care manager)* *"When they get pregnant, they drop out of school, so they cannot attain the purpose for which they came to school, so they end up dropping out of school" (Pedagogic inspector, basic education)*
Inadequate implementation	50.0	81.8	0.038		*"None" (Male Lawyer)* *"Following this, our education*

of comprehensive sexuality education in school, no specific topic					*includes civics education, which is part of the curriculum. We have health education, which is part of the curriculum, where children are educated on issues related to sex, keeping themselves safe, and avoiding delinquency to prevent sexual abuse. They also cover topics on reproductive organ awareness. They also cover what can cause pregnancy and what can prevent it; these issues are discussed in the classroom. Children are taught this to help them stay safe (interviewer: So, there is no subject on SRH specifically?) No, they are just topics in subjects"*
Mechanisms that exist to support pregnant schoolgirls and adolescent mothers	-		81.9%	Qualitative	*"Very poor" (Pastor)*

Comprehensive sexuality education implementation in schools was generally perceived to be low and inadequate. Although primary school SRH courses were more detailed, secondary school courses were not taught as standalone subjects; instead, they were integrated into other subjects: *"This is taught in other subjects, just in a summarized way within some subjects" (NGO coordinator, youth adviser)*. Teenage pregnancy is mostly linked to school dropout and under-schooling, and the vicious circle is that school dropout further exposes adolescent girls to risky sexual behaviors and the related consequences. The topics that were mostly covered ranged from the protection of sexual organs / private parts, menstruation, keeping oneself safe from sexual abuse, prevention of pregnancy, HIV / AIDS, consent, menstrual hygiene, and STIs. Important topics missing ranged from safe internet use, healthy relationships, STIs, contraception, to gender-based violence (Table 4). Teachers were generally perceived as not adequately prepared to provide SRH information and counseling: *"Not very prepared as it is mostly incorporated in other activities" (Female health care manager); "Poorly prepared" (Male Pastor); "Not prepared" (Male Lawyer)*. Stakeholders argued that it will be challenging to have SRH as a sex-differentiation topic because there cannot be a topic on SRH specifically for females or for males because they are mixed: *"It will be challenging for us in public school to make a topic on that specifically for females, because they are mixed" (Pedagogic inspector, basic education).* Several mechanisms were highlighted as supporting pregnant schoolgirls, like the favorable legal context *"Favorable laws which protect pregnancy and extend this to breastfeeding mothers" (Female health care manager)*, the social welfare institution *"Social affairs" (Female health care manager)*, and encouragement and psychological support

"Encouragements for them not to feel that they are left out" (Pedagogic inspector, basic education). However, the overall dynamics were perceived as inadequate or nonexistent: *"Very poor" (Male Pastor)*. As for improvements needed in schools to enhance SRH empowerment, key informants recommended that they should enhance the **Community, Culture, and Gender Norms** subject on moral education to capture more aspects of SRH and overall effective integration in the curriculum, make the environment safer for adolescent girls, enhance SRH education, foster SRH services equipped with professionals/experts, coaching, educative talks and advice, and allocate a specific subject to SRHE.

Table 5. Community, Culture, and Gender Norms as Barriers to SRHE of Adolescent Girls

Indicator	**Barriers**		**χ2-test (P-value)**	**Evidence type**	**Quotation**
	Adolescents	**Stakeholders**			
Gender inequality / Preference for male authority	61.5	59.1	0.872		*"Restriction in decision making" (Female health care manager)* *"To serve as next of kin" (Male Pastor)*
Sexuality taboos	29.4	36.4	0.616	Quantitative vs qualitative	*"When a girl is pregnant, you see her limited by the family not to further any other thing, so the girl now gets angry and goes out to fend for themselves, so it makes them very vulnerable in that state" (Female social affairs counselor).*
Traditional practices	25.7	27.3	0.905		*"You know that we Africans have our own tradition. So, we are not yet at the level where we can freely communicate those things with our daughters. So, we find it very uncomfortable talking about sex with our children. So, we expose those girls to vulnerability because we don't discuss it with them; we don't create awareness in them, and that is why they are facing this type of problem" (Pedagogic inspector, basic education)*
Child marriage	8.1	18.2	0.234		*"This early child marriage hinders them a lot. At times they give up" (Female health care manager)*
Interculturalism	12.2	18.2	0.552		*"Forced migration" (Female health care manager)*
Marginalization of pregnant adolescents		18.2		Qualitative	*"When a girl is pregnant, you see her limited by the family not to do anything else, so the girl now gets angry and goes out to fend for herself, so it makes them very vulnerable in that state" (Female social affairs counselor)*

Class distinction (Discrimination between high- and low-class people)		9.1			*"Class distinction" (Male Lawyer)*
Stigma		9.1			*"They close up and seek help from peers" (Female health care manager)*

Gender inequality/preference for male authority, sexuality taboos, traditional practices, interculturalism, marginalization of pregnant adolescents, child marriage, and class discrimination were barriers that hindered the SRH empowerment of adolescent girls. Marginalization of pregnant adolescents in their families increases their SRHE vulnerability, as they are abandoned and must go out and fend for themselves, and this can foster unsafe abortion (Table 5). Key informants emphasized that cultural beliefs that support adolescent girls' SRH empowerment were essentially abstinence: *"No sex before marriage; yes abstinence, they should abstain" (Wise woman traditional leader)*. It was argued that sexuality taboos and stigma prevent adolescent girls from opening up to the indicated people, thus falling prey to misinformation or misorientations from friends: *"They close up and seek help from peers" (Female health care manager)*. Poverty contributed to risky sexual behavior and transactional sex, fostering inadequate provision of needs and hindering education. Homes with a high propensity to induce adolescent girls into risky sexual behaviors were poor homes, separated-parent homes, and homes with dead parents.

Individual Agency and Empowerment

Table 6. Individual Agency as Barriers to SRHE of Adolescent Girls

Indicator	**Barriers**		**χ2-test (P-value)**	**Evidence type**	**Quotations**
	Adolescents	**Stakeholders**			
Controlled access to information		72.3		Qualitative	*All these media, including social media, should be content-controlled" (Wise woman, female traditional leader)*
SRH education	14.6	45.5	0.005	Quantitative Vs Qualitative	*"It is good to teach young girls those things to prevent early pregnancies and diseases" (male traditional leader); "Poor education" (Female health care manager) "You know that we Africans have our own tradition. So, we are not yet at the level where we can freely communicate those things with our daughters. So, we find it very uncomfortable talking about sex with our children. So, we expose those girls to vulnerability because we don't discuss it with them, we don't create awareness for them, and that is why they are facing this type of problem" (Pedagogic inspector, basic education)*
Economic	23.7	54.5	0.019		*"They can't get their immediate needs"*

empowerment					*"Lack of necessities" (Male Pastor)* *"Poor background" (Male Youth adviser)*
Anxiety/depression	6.5	36.4	0.000		*"A lot of them that I have come across have the mindset of killing themselves; a lot of depression, anxiety; it makes them reserved; they don't even want to open up. It takes a lot for someone who has high acute to talk to them, let them, using shrewd words before they can open up" (Female social affair counselor);* *"Anxiety/depression making them not to focus on education" (Female health care manager)*
Health-seeking behavior	10.7	54.5	0.000		*"Some of them deny" (Female health care manager)*
Sexual relationships / Can make informed decision	13.6	27.3	0.197		*"Very often to the extent of engaging in unhealthy activities" (Female health care manager)*
Access to information through digital media and social media	6.7	54.5	0.000		*"Lack of proper information" (Male Pastor)*

Inadequate controlled access to information, SRH education and economic empowerment, anxiety/depression, improper health-seeking behavior, questionable sexual relationships or ability to make informed decisions, and access to information through digital and social media, among others, were highlighted in this frame. However, perceptions differed sharply between adolescent girls and key informants (Table 6). Key informants emphasized the inadequacy of SRH education "*They are not knowledgeable, not at all. Like the case of last month, the girl told me that they had sex in January, while the boy said they had sex by November or last year. So, the pregnancy was about five months and two weeks, and the girl said, "No, mum, it's four months," so when we did further echography and whatnot, we saw that the boy was telling the truth. So, the boy knew more than the girl, and given her age, she falls under the adolescent category, so she didn't know. They don't really know, so I suggest that they should educate them, organize seminars to teach them more about this because they don't really know" (Female social affairs counselor)*. Regarding health-seeking behavior, some stakeholders perceived reluctance, as some adolescent girls shy away from services, and this could be magnified by lack of knowledge about SRHE mechanisms and the opportunities offered *"Lack of knowledge" (Male Lawyer).* As argued by a social affairs counselor, *"Many adolescent girls have the mind of killing themselves, a lot of depression, anxiety; it makes them be reserved; they don't even want to open up. It takes a lot for someone who has high acute anxiety to talk to them, let them, using shrewd words before they can open up* (*social affairs counselor*). Anxiety and depression were also perceived as hindering

their education. Peer influence, *"Very often to the extent of engaging in unhealthy activities" (Female health care manager), and exposure to inadequate information, "Lack of proper information" (Male Pastor),* could mislead adolescent girls. Factors enhancing girls' confidence and self-efficacy in making informed SRH decisions were education with particular emphasis on the participation of the family *"When the family is there, they educate them and they then have self-confidence and it help them to take care of themselves" (Female social affairs counselor);* economic empowerment *"At times they lack money, they cannot afford their needs and this makes them to lose confidence. So, if the family helps them trained to do something, it will help then regain confidence" (Female social affairs counselor),* and the belief that giving chance to adolescent girl to further her studies will enhance her self-esteem *"At times, when the family allow them to further their education, it makes them to regain confidence" (Female social affairs counselor).* Barriers to reporting sexual violence and care-seeking were lack of knowledge, lack of adequate follow-up of the victim to ensure adequate recovery, fear of opening up, stigmatization, and fear of revenge from the perpetrator of sexual violence if exposed. Protection mechanisms could be strengthened by organizing a clear referral pathway, educating parents through seminars, encouraging them to talk more with their girls, educating parents to open up, stopping indecent dressing as it can enhance sexual appetite in men, and relying on NGOs' support.

Health System and SRH services

Table 7. Health System and SRH Services as Barriers to SRHE of Adolescent Girls

Indicator	Barriers		χ2-test (P-value)	Evidence type	Quotation
	Adolescents	Stakeholders			
Effectiveness of current prevention interventions		54.5		Qualitative	*"Not very effective" (Female health care manager)*
Provider attitude and confidentiality	16.9	40.8	0.040	Quantitative Vs Qualitative	*"Most often they are not on seat or are irregular" (Female health care manager)*
Availability of referral pathways	-	45.5			*"By o*rganizing a clear referral pathway" *(Female health care manager)*
Availability of health facilities	16.8	27.3	0.359		*"In Tiko health district, the health facilities are there except that the client does not want to come to the health facility" (Female health care manager)*
Effective integration	16.8	27.3	0.362		*"Integrated with health packages for health facilities" (Female health care manager) [positive quotation]*
Accessibility	16.4	18.2	0.874		*"Accessibility to SRH*

					services for adolescent girls within the country" (Female health care manager) [positive quotation]
Cost	-	18.2		Qualitative	*"Cost" (Female traditional leader)* [negative quotation]

Hurdles to the health system contribution to SRH of adolescent girls ranged from the ineffectiveness of current prevention interventions, inadequacy of provider attitude and confidentiality, inadequate availability of referral pathways and health facilities, ineffective integration, accessibility, and cost (Table 7). Challenges in accessing adolescent-friendly SRH services ranged from confidentiality, provider attitude, cost, and distance. Overall, these challenges were perceived to a very low extent, except for provider attitude and confidentiality. The health system was mostly challenged by complications following unsafe abortion *"Management of complications" (Male Lawyer)*. Key informants generally argued that the health system needed much more to strengthen its capacity to foster SRH empowerment among adolescent girls: *"Much is still to be done" (Female health care manager)*. Referral pathways were available, though inadequate, and helped in handling sexual violence survivors, pregnant adolescents, and girls requiring psychosocial support. They suggested creating an independent center for adolescents "*Creation of an independent center for the adolescents*," (female *health care manager)*. Barriers to post-abortion care were cost and trauma: *"Sometimes it can lead to severe trauma, so we have to call the family to counsel them, to explain to them why their child had to behave like that, that they cannot throw the child" (Female social affairs counselor)*. Availability of health facilities, effective integration, accessibility, and cost were not major concerns.

Conflict, Displacement, and Humanitarian Context

Table 8. Conflict, Displacement, and Humanitarian Context as Barriers to SRHE of Adolescent Girls

Indicator	**Barriers**		**χ2-test (P-value)**	**Evidence type**	**Quotations**
	Adolescents	**Stakeholders**			
Displacement has increased vulnerabilities	82.0	100	**0.122**	Quantitative Vs Qualitative	*"These internally displaced people are here because we have this crisis that is still going on and has not yet been resolved, so we have this situation that has affected so many girls who have been displaced from their original homes. So, because of the displacement from their original homes, they come to new areas, so they are forced to do things that are not comfortable, maybe because*

					they have lost their parents because of the war, so that makes them very, very vulnerable. So, you find some houses where they are not with their parents; they live with relatives, so they might not get the treatment they are supposed to have. Some of them are exposed to hawking, and through that hawking they might be exposed, mostly the younger ones" (Pedagogic inspector, basic education)
Displacement, change in lifestyle, interculturalism and exposure to risky SRH behaviors	84.6	63.6	0.061		*"People moving from where they are to a place that they are not used to can affect them in one way or the other" (Female health care manager)*
Hardship and risky sexual behaviors	82.6	72.7	0.397		*"Plunged them to hardship" (Female health care manager) "Let us say maybe a few people were living in a house, maybe two, and you are now ten of you, and maybe you don't have the finance; this can lead to hardship" (Female health care manager)*
Chaotic environment/neighborhood, promiscuity, sexual exploitation / transactional sex, teenage pregnancy, lawlessness and risky sexual behaviors	79.9	63.6	0.188		"Sexual violence" (Male Lawyer) "Theft" (Female health care manager)
Disruption of education, school dropout, and risky sexual behaviors	80.7	54.5	0.032		"School dropout" (Male Lawyer)

The socio-political crisis affects adolescent girls' SRH in a myriad of interconnected ways. Forced migration or displacement has disrupted the social fabric, family organization, and economic viability, creating unforeseen risks and challenges in integrating into a new or unfamiliar environment. Hardship leading to transactional sex was also highlighted. An increase in household size with inadequate accommodation led to poor sex differentiation, thus increasing the risk of gender-based violence between boys and girls. Among others was sexual exploitation, as men take advantage of the economic vulnerability of adolescent

girls. Key informants and adolescent girls agreed that displacement has increased vulnerabilities as it fostered sexual exploitation, early marriage, school dropout, teenage pregnancy, STIs, and unsafe abortion (Table 8). Interventions implemented to address these displacement-related vulnerabilities ranged from sustaining education and sustained sensitization to subsidies or financial support for the vulnerable and NGO support. With respect to subsidies, this key informant deplored the irregularity *"I think they could give subsidies or financial support to those that are really vulnerable, but looking at the state of the country, those subsidies are not forthcoming, because when it was coming, it could help them do something on their own. For instance, in 2024 it came, and we shared it with those that came to the office, but from 2024 that we applied up till date it has not come, and at times good wishers display themselves; our partners contribute; for instance, when a case comes to our office, we can send to our partner; they help, they help a lot" (Female social affairs counselor).* As for the gaps remaining in interventions, key informants argued that there was still a long way to go *"Naturally, I cannot tell; they still have a long way to go" (Female social affairs counselor), but* emphasized the need for setting a clear referral pathway for management of victims and their protection *"A clear referral pathway for management of victims and their protection" (Female health care manager)*.

Legal, Policy, and Rights Environment

Table 9. Legal, Policy, and Rights Environment as Barriers to SRHE of Adolescent Girls

Indicator	Barriers		χ2-test (P-value)	Evidence type	Quotation
	Adolescents	Stakeholders			
Awareness of rights	6.5	63.6	0.000	Quantitative Vs Qualitative	*"Education of girl child" (Male Lawyer)*
Adolescent girls' involvement in planning, implementation, or evaluation of SRH programs	-	90.9		Qualitative	*"Yes, when we have our activities, we usually call them on the phone through their parents" (Female social affairs counselor)*
Implementation / multi-sectoral approach	-	90.9			*"Lack of enforcement" (Male Lawyer)*

Regarding policies or programs supporting adolescent SRH in Cameroon, key informants argued that policies exist, notably the penal code and regulations in various ministries, but they weakly emphasized implementation and collaboration among offices in line with the multi-sectoral approach (Table 9). Key informants acknowledged that much remains to be done, with diverse and complex challenges, as shown in this quotation: *"We still have a lot to do" (Female social affairs counselor)*. However, a key informant emphasized that the existence of women empowerment centers indicates that something is being done. Current SRH programs reflect the principles of the Maputo Protocol, primarily through education and awareness for adolescent girls. Adolescent girls' involvement in planning, implementation, or evaluation of SRH programs was still quite poor. It should also be considered in policy reforms toward strengthening adolescent girls' SRHE, besides improving sensitization and training more policymakers and implementers, as they

indicated, enhancing follow-up, subsidies, supervision of activities, community collaboration in identifying and reporting violence for investigation, regular and sustained awareness and sensitization at school and community levels, effective communication and dialogue with the adolescents, encouraging the adolescent to open up and to speak out, setting a clear referral pathway for management of victims and their protection, and a goal-oriented approach by setting targets that should be met. At the sector and household levels, key informants recommended effective communication and dialogue with adolescents, encouraging them to open up and speak out, and parental guidance. At the school level, they emphasized regular, sustained awareness and sensitization, and effective integration into the curriculum. At the community level, they emphasized collaboration to identify and report violence for investigation; sensitization and education; enhancing safer neighborhoods free from promiscuity, substance abuse, and noise pollution, among others; and equipping communities with basic social amenities (Figure 1). At the health system level, the study recommended supervision, staff training, and donating prevention kits or reducing prices. At the policy level, the study recommended refining policies to incorporate adolescents' needs and ensure enforcement.

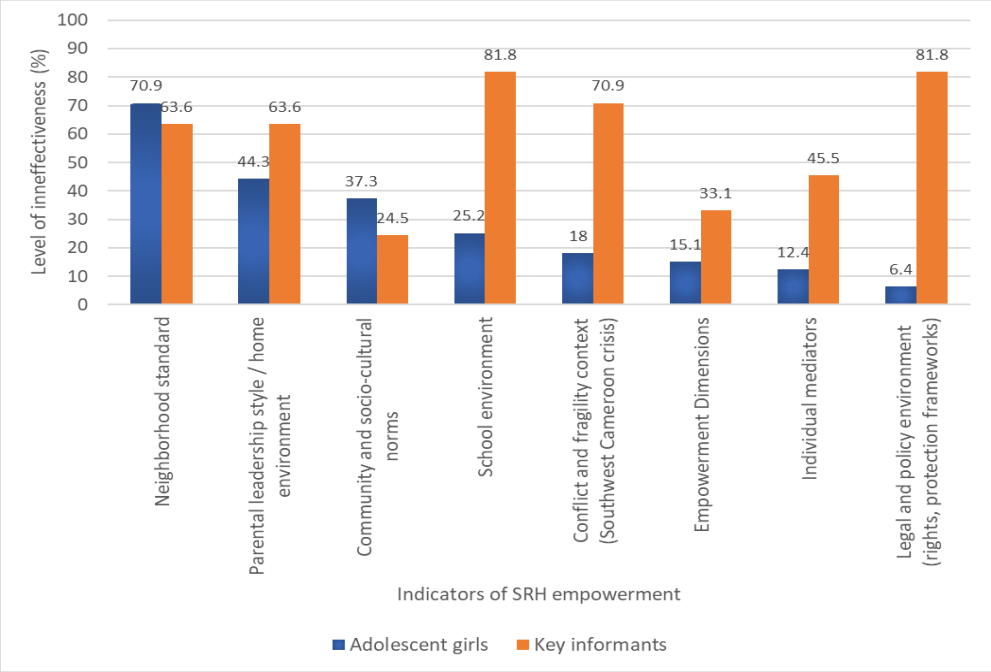


Figure 1. Ineffectiveness of Indicators of SRH Empowerment of Adolescent Girls

Discussion

The study examined governance and implementation gaps in establishing an effective operational mechanism to enhance and sustain adolescent girls' SRHE. These findings highlighted that successful institutionalization of adolescent girls' SRHE is paramount to effectively curb sexuality-related vulnerability inherent to the home environment, school environment, community and socio-cultural norms, legal and policy environment, conflict and fragility context, individual mediators, and the empowerment dimensions, with particular reference to the healthcare, counseling, and social services. This aligns with the Tanzanian context, where suggestions included youth-supportive policies, establishing school clubs that provided sexual and reproductive health education, and government stakeholders' commitment [27]. This study context unfolded a number of challenges generally interconnected and, by so doing, emphasizing the need for sustainable

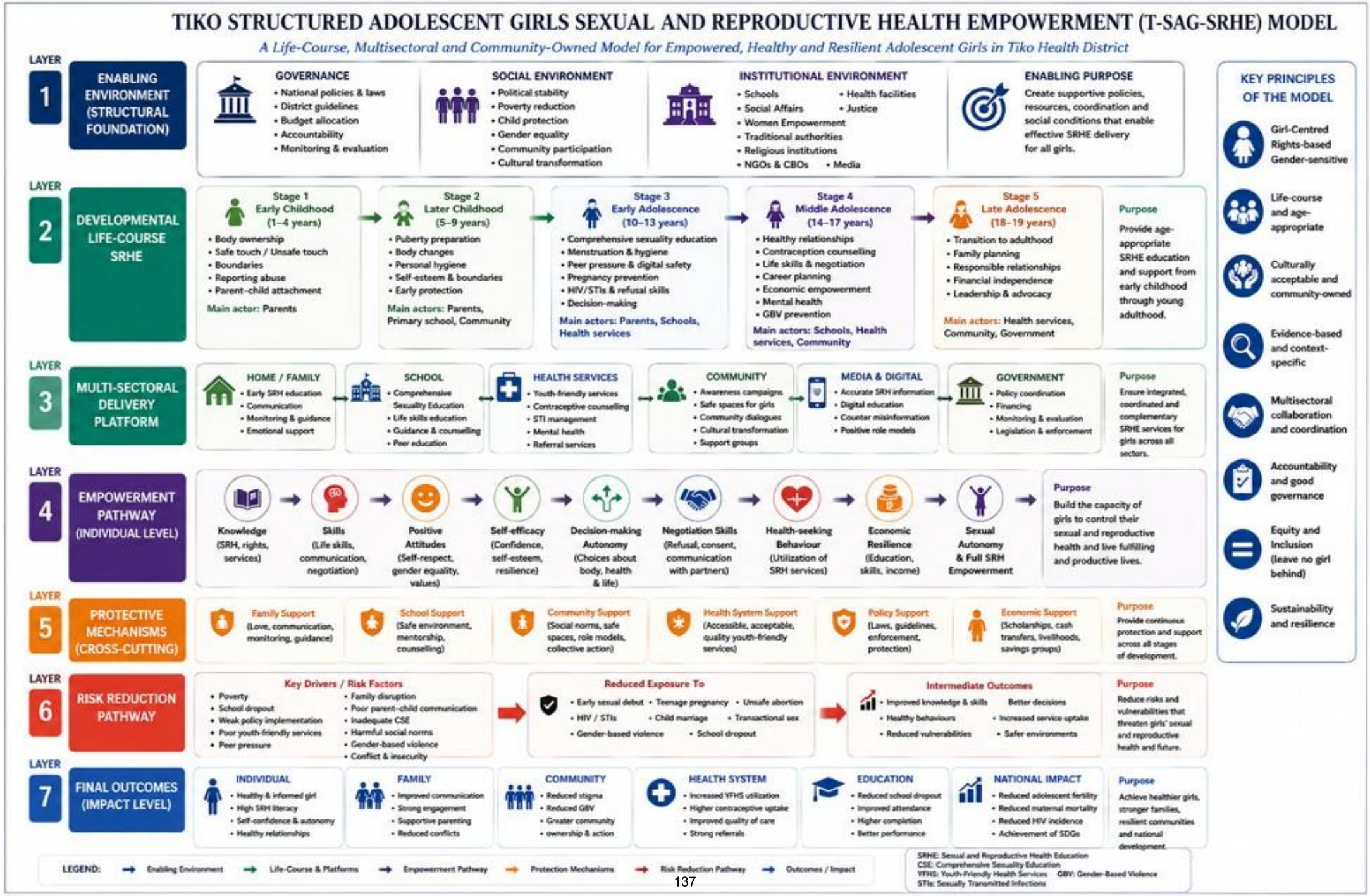
strategies that address vulnerabilities stemming from the ongoing socio-political crisis, curbing structural inequalities, traditional barriers, cultural and religious beliefs, and stigma while strengthening health systems, intersectoral cooperation, comprehensive, culturally tailored education, poverty alleviation, economic empowerment of adolescent girls considering their stages of development, and clear and enforced regulatory frameworks which are essential if our vision for equitable and sustainable SRH services should be achieved. These insights offer practical guidance for public policy and program design, particularly for addressing the needs of marginalized adolescent populations [2].

The empowerment dimension considers three major axes: agency, or the ability to make informed SRH decisions; resources related to access to SRH information and services; and achievement, as reflected in the actual utilization of services and healthy behaviors, though these were generally inadequate, unstructured, and poorly interconnected. Previous work emphasized the need for sustainable strategies to address structural inequalities and stigma while strengthening health systems that prioritize quality, equity, and integration, and include accountability mechanisms for users and providers [28]. In this study context, major loopholes included inadequate referral pathways, questionable attitudes among health personnel, and insufficient collaboration with adolescents. While governments have reaffirmed many commitments, policy development and program implementation still fall short of delivering on them. Future success requires increased political will and engagement of young people in the formulation and implementation of policies and programs, along with increased investments to deliver and scale comprehensive sexuality education, health services that are approachable and not judgmental, safe spaces programs, especially for vulnerable girls, and programs that engage families and communities [29]. Intersectional interaction and collaboration among sectors and stakeholders are needed to develop a multi-level, comprehensive model for empowering adolescent girls [30], and this study context also highlighted this as a salient concern.

Conclusion

The SRH empowerment of adolescent girls was a major preoccupation for various stakeholders, who undertook proactive and reactive actions at various levels to address its related preoccupations. However, gaps in governance and policy conception and implementation remained a concern. The findings revealed many breaches in adolescent girls' SRHE, ranging from early engagement in sex, transactional sex, unintended pregnancy, school dropout, abortion, and, more critically, unsafe abortion, and low perception of contraceptives, though preference was expressed for condoms. Although the region's socio-political crisis contributed through poverty, internal displacement, and family disruption, other salient facilitators included inadequate policies and governance, with the education sector still lacking structure and specificity. To improve and sustain adolescent girls' SRHE, stakeholders suggested the refinement of SRH education, notably in secondary school, and the proper implementation of existing policies in a multi-sectoral approach while striving to end the crisis, alleviating poverty and fostering early home-based education, comprehensive / intensified school-based education with effective integration in the curriculum, intensified community-based education and awareness, and education through mass media while intensifying from early adolescence.

Figure 2. Proposed T-SAG-SRHE Model for Structured Adolescent Girls' Sexual and Reproductive Health Empowerment in the Tiko Health District.



Although access to information through mass media and social media was moderately satisfactory, the content available to adolescents needed to be controlled. The economic empowerment of adolescent girls, considering their stages of development, was encouraged to reduce dependence and the risk of transactional sex, while deploring the growing laziness among youth as a major drift that should be corrected. It was advocated that repressive measures be taken to deter perpetrators of sexual abuse and, among others, that adolescent girls who engage in poor behavior should be punished to deter their continuation. Stakeholders recommended involving adolescent girls in SRH-related activities and considering their opinions in policy conception and implementation. A means to ensure the inclusion of SRH in health sector planning and make functioning health systems work for SRH is to strengthen participation in program-based approaches and sector-wide approaches (SWAps) and promote attention to SRH within national educational, health, legal, social, and law-enforcement sectors, not discriminately but in integration, strategic planning, and budgeting, while setting adequate referrals and interconnection pathways. In addition, the most effective and cost-efficient way to ensure SRH issues are part of the humanitarian response is to incorporate them into emergency preparedness plans and build national preparedness capacity from a structured, multi-sectoral perspective. The proposed T-SAG-SRHE model (Tiko - Sexual and Reproductive Health Empowerment of Adolescent Girls) (Figure 2) is designed to address governance, policy, sociocultural, and health system-level barriers that affect adolescent girls' SRHE in the Tiko Health District in Cameroon's Southwest Region. It is a multi-sectoral, participatory, adolescent-centered model that incorporates comprehensive sexuality education, equitable access to adolescent-friendly health services, active adolescent participation, family and community support, and stronger institutional accountability. The model aims to strengthen adolescents' capacity to make informed decisions, achieve reproductive autonomy, adopt health-seeking behaviors, and achieve equitable SRHE outcomes by integrating policy, service delivery, and adolescents' lived experiences. The researchers propose testing the model's efficacy and potential for wider application through pilot programs in the local context, with appropriate stakeholder involvement and long-term evaluation.

Limitations

This study was conducted in a region facing socio-political instability since 2016, which made working in rural/remote communities challenging. Despite these constraints, the study achieved its objectives.

Recommendations

To enhance the effectiveness of SRH empowerment of adolescent girls, the following recommendations were made:

- Ending the socio-political crisis rocking the region since 2016.
- Making SRHE a specific subject in secondary school.
- Enhancing education and awareness at home, community, school, health centers, and through mass media and social media while controlling for unsuitable content.
- Enhancing collaboration among stakeholders; and
- Fostering a participatory approach whereby adolescent girls are active actors, where conducive, in actions geared toward enhancing their SRH empowerment.
- Piloting of the T-SAG-SRHE model to ascertain its effectiveness, and plan large scale implementation.

Acknowledgements

The authors sincerely appreciate the study participants, research assistants, and Tiko District Health Team members, as well as key informants at the regional level, for their

support and contributions to this research. Their dedication and collaboration were instrumental in successfully completing this study.

Disclaimer

The views and opinions expressed in the submitted article are the authors' own and not the official position of the affiliated institutions.

Competing Interest Statements

The authors declare no competing interests with respect to this study and publication.

Authors Contributions

Binsila B. B. and Bodzewan E. F. participated in all stages of this paper, from study design and methods to data collection, analysis, and writing. Nana C. participated in methods and data analysis.

Ethical Approval

Ethical approval was obtained from the Southwest Regional Delegation of Public Health, Ref. No1292/CRERSH/SW/C/05/2026.

Data Availability

Data for this study are available and can be accessed if requested.

Funding

This study was conducted as part of a Ph.D. program and received no external funding from public, commercial, or non-profit organizations.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art011

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Effectiveness of New-Generation Long-Lasting Insecticidal Nets in Reducing Malaria Incidence: Evidence from a Community-Based Study in Mangoum, Cameroon

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Cite this article as: Bate FBT, Ali IM, Queenta EM, Oyebog FE, Agbor ED, Nche NN, Velda EB. Effectiveness of new-generation long-lasting insecticidal nets in reducing malaria incidence: evidence from a community-based study in Mangoum, Cameroon. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art011**

Received: 10.07.2026

Accepted: 06.10.2026

Published: 30.10.2026

Article Type: Original Research

Abstract *In Cameroon, malaria remains a major public health burden, particularly in semi-rural communities such as Mangoum. Malaria incidence remains high, prompting the introduction of new-generation LLINs designed to improve vector control, overcome insecticide resistance, and enhance durability, despite widespread distribution of Long-Lasting Insecticidal Nets (LLINs). Evidence on their effectiveness in community settings is however limited. This study looked at the effectiveness of new-generation LLINs on malaria transmission in Mangoum, Foumbot. A community-based quasi-experimental design was conducted among 395 households receiving new-generation LLINs. Structured questionnaires via Kobo Collect were used to collect multistage sampling selected participants, and quantitative data on LLIN ownership, usage patterns, and malaria cases before and after distribution. Descriptive statistics and Chi-square tests in SPSS version 25 were used to analyze data, with $p < 0.05$ set as significance. Analysis showed strong associations between LLIN utilization and motivation to use nets ($\chi^2(9) = 60.079$, $p < 0.001$), net sufficiency ($\chi^2 = 27.219$, $p = 0.001$), and perceived effectiveness ($\chi^2 = 29.54$, $p < 0.001$). Households reporting more than five malaria cases decreased from 8.6% to 1.8% ($\chi^2 = 62.39$, $p < 0.001$), LLIN usage correlated with malaria reduction ($\chi^2 = 26.237$, $p < 0.001$), and longer net use was associated with fewer cases ($\chi^2 = 31.442$, $p < 0.001$), which signifies malaria incidence declined significantly after distribution. A 40.7% decline in confirmed malaria cases was confirmed by health facility records. These findings demonstrate that malaria incidence is significantly reduced at the household level by new-generation LLINs, and that the effectiveness of LLIN-based malaria control strategies in similar community settings could further be enhanced by strengthening household coverage and promoting consistent nightly use.*

Keywords *Community Uptake, Cameroon, Effectiveness, Household Utilization, Malaria Incidence, New-generation LLINs.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art011

Introduction

Problem to be solved

Globally, particularly in sub-Saharan Africa, malaria remains one of the most significant public health challenges, which carries the highest burden of disease. Globally, approximately 249 million malaria cases were reported, with the African region accounting for most cases and deaths in 2022 [1]. Through bites of infected female *Anopheles* mosquitoes, malaria which is transmitted to humans is caused by protozoan parasites of the genus *Plasmodium* [2, 3].

The disease continues to cause high morbidity and mortality in endemic countries such as Cameroon despite advances in malaria control, accounting for over 40% of outpatient consultations and 30% of hospital admissions [4]. Due to environmental conditions conducive to mosquito breeding, coupled with socioeconomic barriers that limit access to preventive tools, rural communities, such as Mangoum in Foumbot Subdivision, experience high transmission [5, 6].

The effectiveness of conventional LLINs is increasingly threatened by pyrethroid resistance in Anopheles mosquito populations, although they have been widely distributed, reducing the protective efficacy of these nets and potentially reversing progress in malaria prevention [7-9]. In addition, behavioral factors, cultural beliefs, and inconsistent net usage influence the actual impact of LLINs [10, 11]. There is thus an urgent need to assess the effectiveness of new-generation LLINs in community settings where these challenges persist [5, 6].

Existing Solutions for the Problem

Globally, several malaria control strategies have been implemented to reduce transmission [12, 1].

Conventional Long-Lasting Insecticidal Nets (LLINs)

Conventional LLINs provide both physical and chemical protection against mosquitoes. Treated with pyrethroid insecticides, they repel or kill vectors and have contributed substantially to reductions in malaria incidence [13, 14].

New-Generation Long-Lasting Insecticidal Nets

To address pyrethroid resistance, new-generation LLINs have been developed:

- PBO-treated LLINs: Contain piperonyl butoxide, a synergist that inhibits mosquito detoxification enzymes, restoring pyrethroid efficacy [15, 16].
- Dual-active ingredient LLINs: Combine pyrethroids with additional chemicals, such as pyriproxyfen, disrupting mosquito reproduction and enhancing mortality [16, 17].

Indoor Residual Spraying (IRS)

Mosquitoes resting indoors after feeding, complementing LLIN coverage and reducing vector density Indoor residual spraying is targeted by Indoor Residual Spraying [15].

Chemoprevention and Other Strategies

Other interventions include:

1. Intermittent Preventive Treatment in Pregnancy (IPTp)
2. Seasonal Malaria Chemoprevention (SMC)
3. Perennial Malaria Chemoprevention (PMC)
4. Improved malaria diagnosis and treatment services.

Behavioral and Community Engagement

Community-based programs that promote awareness, education, and behavioral change improve LLIN utilization and adherence, enhancing the effectiveness of preventive interventions.

Best Existing Solution

For areas with high pyrethroid resistance, among malaria control interventions, new-generation LLINs, particularly PBO-treated nets, are the most promising. These nets inhibit mosquito detoxification enzymes, restoring pyrethroid efficacy and improving mosquito mortality [15-17].

Compared to conventional nets, field trials in Tanzania and Uganda have shown that PBO-treated LLINs significantly reduce malaria prevalence. As a result, the World Health Organization recommends their use in regions with confirmed pyrethroid resistance. These nets represent the most effective currently available solution for malaria vector control in high-resistance settings [19].

Limitations of Existing Solutions

New-generation LLINs face several limitations, despite their benefits:

- Even to new chemical combinations mosquitoes may develop resistance, compromising long-term efficacy - evolution of insecticide resistance [8, 20].
- Effectiveness is reduced by heat discomfort, improper net hanging, inconsistent use, and seasonal neglect - usage and behavioral barriers [10, 18].
- Due to logistical constraints, distribution gaps, and financial limitations remote communities may face delays - distribution and accessibility challenges [14].
- Net lifespan is reduced by frequent washing, physical damage, and poor maintenance - durability and maintenance issues [21].
- Net utilization and protective effectiveness are influenced by housing conditions, environmental factors, and cultural beliefs - contextual and socio-cultural factors [18].

Achievements of the Intervention

LLIN interventions have produced substantial global impact:

1. Between 2000 and 2019 due to preventive measures, including LLINs, malaria mortality declined significantly [12].
2. More than 1.5 billion malaria cases were prevented, and approximately 7.6 million deaths were averted worldwide [19].
3. In areas with pyrethroid resistance, new-generation LLINs have shown superior performance, thus reducing malaria transmission effectively [16, 22].

At the community level, this study contributes by:

1. Evaluating effectiveness of new-generation LLINs in Mangoum.
2. Examining community uptake and usage patterns.
3. Identifying barriers and facilitators of LLIN use.
4. Providing evidence-based recommendations for malaria prevention strategies.
5. Supporting national malaria control policies with local evidence.

Schematic Diagram / Graphical Abstract

The conceptual framework in figure 1 above shows that the effectiveness of new-generation LLINs in reducing malaria depends on several factors, including education, household size, LLIN availability, health education, cultural beliefs, access to distribution, and personal motivation. These factors influence LLIN usage (regular use, proper installation, and maintenance), which serves as the link between the determinants and the outcomes. Effective LLIN use leads to reduced malaria cases, lower treatment costs, and improved perceptions of LLINs, while age, gender, marital status, occupation, and housing type moderate these relationships. They act as moderating variables because they influence the strength or direction of the relationship between the determinants (education, household size, LLIN availability,

health education, cultural beliefs, access to distribution, and personal motivation) and effective LLIN use.

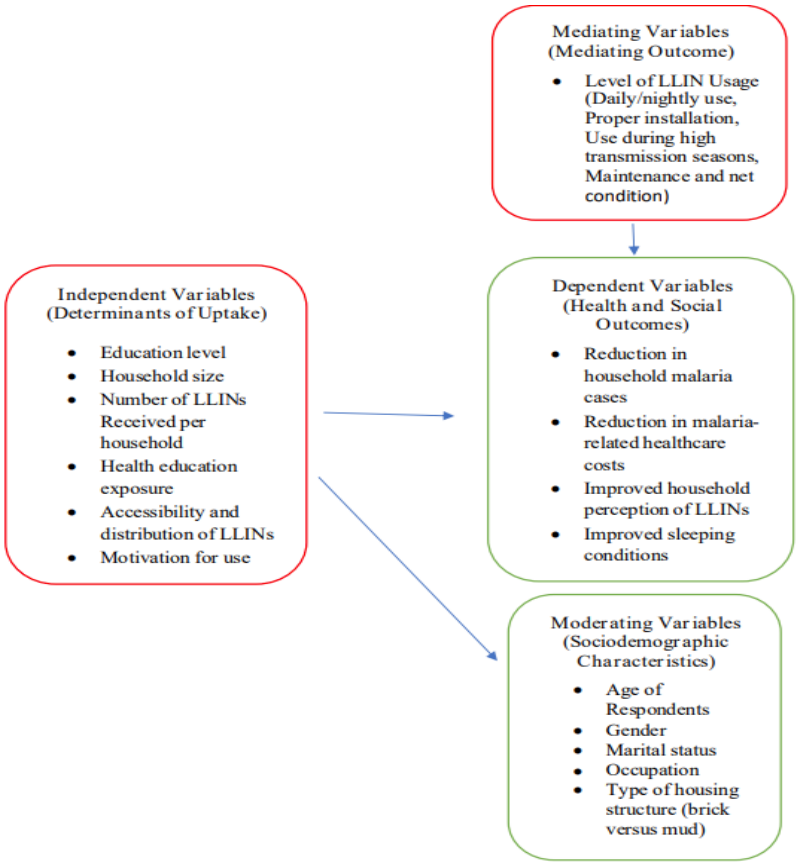


Figure 1. Conceptual Framework

Objective of the Study

General Objective:

To investigate the effectiveness of new-generation LLINs in reducing malaria transmission in Mangoum, Foumbot, Cameroon.

Specific Objectives:

To assess community uptake and utilization of new-generation LLINs in Mangoum, Foumbot, Cameroon.

To measure the impact of new generation LLINs on malaria incidence before and after net distribution.

Novelty of the work

This study is novel due to:

Context-specific evidence: Provides field-based, measurable data on malaria incidence and LLIN effectiveness in a semi-rural Cameroonian community, addressing a critical gap in epidemiological evidence.

Integration of multiple data sources: Combines survey data and health facility records to generate a comprehensive quantitative assessment of net utilization and impact on malaria transmission.

Quantitative evaluation: Employs structured household surveys to measure statistical associations between LLIN usage, household coverage, and reductions in malaria incidence.

Materials and Methods

Description of the Study Site

The study was conducted in Mangoum, a locality situated in the Foumbot Subdivision of the West Region of Cameroon, within the Noun Division. The area experiences a tropical climate characterized by two distinct seasons: a

rainy season extending from March to October and a dry season from November to February. These climatic conditions create a favorable environment for year-round mosquito breeding, which sustains persistent malaria transmission in the region.

Mangoum is predominantly rural with semi-urban pockets, representing a mixed epidemiological setting for malaria transmission. The population is largely engaged in agricultural activities, including subsistence and cash crop farming such as maize, beans, coffee, and vegetables. The community is ethnically diverse, with the Bamileke ethnic group forming the majority, alongside other groups who migrated to the area for farming and trade opportunities.

Malaria remains a major public health concern in Foumbot, ranking among the leading causes of morbidity and mortality, particularly among children under five years and pregnant women. Although the area has benefited from national LLIN distribution campaigns and malaria control programs, consistent utilization and community uptake remain variable.

Mangoum was selected as the study site due to its high malaria transmission, environmental risk factors, and recent participation in national LLIN distribution campaigns. The community has an estimated population of approximately 20,000 inhabitants, with health services mainly provided by the Mangoum Integrated Health Centre, which offers malaria diagnosis, treatment, and distribution of preventive tools such as LLINs.

The village is traditionally organized into 13 quarters or subsectors, including Mangoum Centre, Mbantou, Bamenjo, Ngangang, Fombap, Goumgoumé, Ngouet, and Nko VI. For geographic precision, the study area was georeferenced using GPS coordinates (Latitude 5.4390°N and Longitude 10.6312°E), and household locations were mapped using Google Earth to facilitate field navigation and spatial coverage during data collection.

Quantitative Investigation

The quantitative component of the study employed a community-based quasi-experimental design to assess the effectiveness of new-generation Long-Lasting Insecticidal Nets (LLINs) in reducing malaria transmission.

The study compared malaria incidence before and after the introduction of new-generation LLINs in the community. Two time periods were considered:

- Pre-intervention period: 2019-2021 (before distribution of new LLINs)
- Post-intervention period: 2022-2024 (after distribution of new LLINs)

This approach allowed the study to evaluate trends in malaria occurrence in relation to LLIN ownership and usage patterns. The intervention itself was not experimentally assigned by the researchers, as LLIN distribution was implemented through a national malaria control campaign, making the study observational but comparative in nature.

The quantitative investigation focused on several key indicators, including:

- Number of malaria cases per household before and after LLIN distribution.
- Household ownership of LLINs.
- Frequency and consistency of LLIN usage.
- Duration of net usage.
- Household perceptions of LLIN effectiveness.

Data were collected from households across selected quarters of Mangoum using a multistage sampling strategy. Initially, 9 out of the 13 quarters were purposively selected to represent geographic, social, and environmental diversity. Within each quarter, systematic random sampling was applied to select households.

The required sample size was calculated using the Cochran sample size formula, assuming a 95% confidence level, 50%

expected proportion, and a 5% margin of error. This produced a minimum sample size of 384 households, but the study ultimately surveyed 395 households to increase statistical reliability.

Description of the Laboratory Methods

Although the study was primarily community-based, health facility malaria records were used as a complementary data source to validate household-reported malaria cases. These records were obtained from the Mangoum Integrated Health Centre and nearby health posts, where malaria diagnosis is routinely conducted using standard diagnostic methods such as microscopy and rapid diagnostic tests (RDTs).

These laboratory-confirmed malaria case records provided secondary epidemiological data that allowed the researchers to compare trends in malaria incidence before and after the distribution of new-generation LLINs. The integration of health facility records strengthened the reliability of the study findings by reducing dependence solely on self-reported household data.

Description of the Statistical Methods used - Quantitative Analysis

Quantitative data collected from households were processed and analyzed using IBM SPSS Statistics version 25. Prior to analysis, survey data collected through KoboCollect were exported to Microsoft Excel for cleaning, verification, and removal of incomplete or inconsistent responses before being imported into SPSS.

The statistical analysis involved three main levels of analysis:

Univariate Analysis

Univariate analysis was used to summarize individual variables using:

- Frequencies
- Percentages
- Means
- Standard deviations

These statistics described variables such as:

- Number of LLINs received.
- Year of distribution.
- Duration of net usage.
- Perceived effectiveness of LLINs.

Likert-scale responses related to strategies for improving LLIN usage were analyzed using mean scores and standard deviations.

Bivariate Analysis

Bivariate analysis was conducted to examine relationships between pairs of variables using the Chi-square (χ^2) test of independence.

Examples of relationships tested included:

- Motivation for LLIN use and consistent net usage
- Household net sufficiency and usage consistency
- Socio-demographic variables and LLIN usage patterns
- Duration of net use and malaria incidence

The Chi-square test helped determine whether significant associations existed between these variables.

Multivariate Analysis

To further identify predictors of LLIN usage, a multiple linear regression analysis was conducted. This statistical model examined the influence of several independent variables simultaneously, including:

- Discomfort while sleeping under nets
- Lack of training on LLIN usage
- Cultural beliefs
- Lack of follow-up by health workers

The regression model assessed the direction and magnitude of influence of each variable on consistent LLIN usage while controlling for the effects of other factors.

Statistical significance was determined using a p-value threshold of 0.05.

https://doi.org/10.21522/TIJAR.2014.13.04.Art011

Results

Community Uptake and Utilization of New-Generation LLINs in Mangoum, Foumbot

The analysis of survey responses from 395 households revealed a high level of community uptake and utilization of new-generation long-lasting insecticidal nets (NG-LLINs) in Mangoum, Foumbot. Across multiple distribution years, the proportion of households reporting LLIN use remained consistently high, with more than 68% of respondents reporting net use, and nightly usage exceeding 80% in most categories (Table 1 and Figure 2). For example, 87.7% of households that received nets in 2020 and 84.5% of those receiving nets in 2022 reported using them every night. These findings indicate widespread adoption of NG-LLINs as part of routine malaria prevention practices in the community.

Table 1. Analysis of NG LLIN Usage in Relation to Household Factors

S. No	Predictor variables	NG LLIN usage	Yes, every night	Yes, occasionally	No	Others	Total	Chi-square (df)	p-value
1.	Year Received NG LLIN	2020	50 (87.7%)	5 (8.8%)	2 (3.5%)	0	57	$\chi^2(12) = 15.565$	.212
		2021	13 (68.4%)	3 (15.8%)	3 (15.8%)	0	19		
		2022	142 (84.5%)	15 (8.9%)	11 (6.5%)	0	168		
		2023	74 (83.1%)	10 (11.2%)	5 (5.6%)	0	89		
		2024	53 (85.5%)	8 (12.9%)	0 (0.0%)	1 (1.6%)	62		
2.	Number of NG LLINs Received	1	103 (77.4%)	13 (9.8%)	17 (12.8%)	0	133	$\chi^2(9) = 27.219$	.001
		2	98 (87.5%)	12 (10.7%)	2 (1.8%)	0	112		
		3	69 (87.3%)	8 (10.1%)	2 (2.5%)	0	79		
		Above 3	62 (87.3%)	8 (11.3%)	0 (0.0%)	1 (1.4%)	71		
3.	Motivation to Use NG LLINs	Fear of Malaria	250 (89.9%)	19 (6.8%)	9 (3.2%)	0	278	$\chi^2(9) = 60.079$	.000
		Health W. Influence	2 (66.7%)	1 (33.3%)	0 (0.0%)	0	3		
		Habit/ Tradition	8 (72.7%)	1 (9.1%)	1 (9.1%)	1 (9.1%)	11		
		Other Reasons	72 (69.9%)	20 (19.4%)	11 (10.7%)	0	103		
4.	People Sleeping Under One NG LLIN	1 Person	32 (72.7%)	6 (13.6%)	6 (13.6%)	0	44	$\chi^2(9) = 17.743$	.038
		2 Persons	133 (85.8%)	14 (9.0%)	7 (4.5%)	1 (0.6%)	155		

		3 Persons	129 (84.9%)	20 (13.2%)	3 (2.0%)	0	152		
		Above 3	38 (88.4%)	1 (2.3%)	4 (9.3%)	0	43		
5.	**Duration of NG LLIN Use**	Less than 6 months	15 (88.2%)	2 (11.8%)	0 (0.0%)	0	17	$\chi^2(15) = 68.519$	.000
		6–12 months	58 (85.3%)	7 (10.3%)	2 (2.9%)	1(1.5%)	68		
		1–2 years	62 (82.7%)	10 (13.3%)	3 (4.0%)	1 (1.3%)	75		
		2–3 years	108 (87.8%)	11 (9.0%)	4 (3.3%)	0	123		
		More than 3 years	85 (83.3%)	11 (10.8%)	6 (5.9%)	0	102		
		I do not know	4 (40.0%)	0 (0.0%)	6 (60.0%)	0	10		

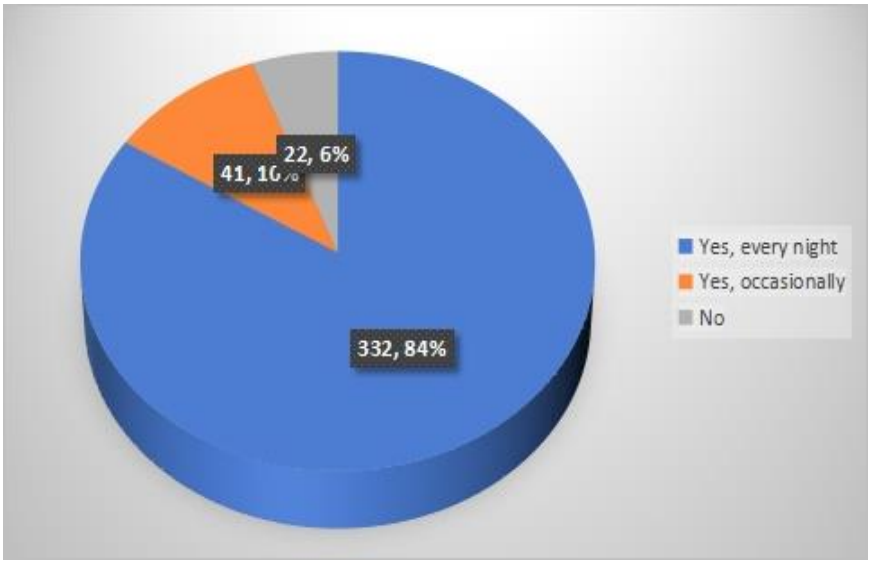


Figure 2. Current use of NG LLINs in the Household for Community Uptake

Statistical analysis demonstrated that several factors significantly influenced LLIN utilization. The number of nets received per household was strongly associated with consistent usage (χ^2, p = .001), with households receiving two or more nets reporting higher nightly usage (87.5%) compared to those receiving only one net (77.4%). Similarly, motivation to use LLINs showed a strong association with consistent use ($\chi^2(9) = 60.079$, $p < .001$). Among respondents who cited fear of malaria as their primary motivation, 89.9% reported nightly net use, compared with 69.9% among those motivated by other reasons such as comfort or routine.

Other variables significantly associated with LLIN uptake included number of people per net (p = .038), duration of net use (p = .000), frequency of washing (p = .000), method of washing (p = .000), belief that LLINs reduce malaria (p = .000), and perceived effectiveness of the nets (p = .000). In contrast, year of net distribution (p = .212) and community belief influence (p = .284) were not statistically significant predictors of utilization.

Regression analysis further identified key determinants of consistent LLIN use (Table 2). Motivation to use LLINs (B = 0.067, SE = 0.021, p = .001) and duration of net use (B = 0.064, SE = 0.022, p = .004) were significant positive predictors of current net use. Conversely, male respondents were less likely to report regular LLIN use compared with female respondents (B = −0.116, SE = 0.054, p = .032). These findings suggest that LLIN uptake in Mangoum is influenced by a combination of behavioral motivation, household net availability, and socio-demographic characteristics, confirming that the majority of households have adopted and consistently use NG-LLINs for malaria prevention.

Table 2. Multiple Linear Regression Predicting Household use of NG LLINs

Predictor Variable	B (Unstd.)	Std. Error (SE B)	Beta (Std.) β	t	Sig. (p)	95% CI (Lower)	95% CI (Upper)
Constant	0.866	0.247	–	3.503	0.001	0.380	1.352
Gender	−0.116	0.054	−0.104	−2.155	**0.032***	−0.223	−0.010
Household size	−0.006	0.030	−0.010	−0.188	0.851	−0.065	0.054
No. of NG LLINs received	−0.047	0.025	−0.098	−1.903	0.058	−0.097	0.002
Motivation to consistently use LLINs	0.067	0.021	0.166	3.234	**0.001***	0.026	0.108
No. of people per LLIN	−0.021	0.033	−0.033	−0.640	0.522	−0.087	0.044
Duration of LLIN use	0.064	0.022	0.148	2.900	**0.004***	0.021	0.108
Main reasons preventing regular use	−0.021	0.014	−0.075	−1.496	0.136	−0.049	0.007
Assistance to repair/maintain LLIN	0.175	0.095	0.095	1.845	0.066	−0.012	0.362
Received info/training on use/maintenance	−0.071	0.033	−0.120	−2.124	**0.034***	−0.137	−0.005
Perceived contribution to malaria reduction	0.104	0.053	0.119	1.962	0.051	0.000	0.208
Change in household malaria treatment expenses	0.064	0.050	0.076	1.287	0.199	−0.034	0.163
Perceived effectiveness vs old nets	0.052	0.040	0.067	1.314	0.190	−0.026	0.130

Impact of New-Generation LLINs on Malaria Incidence before and after Distribution

To determine the effectiveness of NG-LLINs in reducing malaria incidence, paired sample t-tests were conducted comparing malaria cases before and after net distribution among the same households.

Results showed a significant reduction in malaria incidence following the introduction of NG-LLINs. Prior to the distribution of the nets, households reported an average of 2.45 malaria cases, which declined to 1.30 cases after the introduction of NG-LLINs, representing a mean difference of 1.144 cases (Table 3). This reduction was statistically significant ($t(394) = 19.858$, $p < .001$), with a 95% confidence interval ranging from 1.031 to 1.258. The negative correlation coefficient ($r = -0.329$) indicates that households experiencing higher malaria burdens before the intervention recorded the greatest reductions following net distribution.

Table 3. Paired samples T-Test on the effectiveness of NG LLINs in reducing malaria

Comparison	Mean before NG LLIN	Mean after NG LLIN	Mean difference	95% CI of difference	t (df)	Correlation (r)	p-value
Perceived change in malaria	2.45	1.30	1.144	[1.031, 1.258]	19.858 (394)	−0.329	.000
Actual cases after (2022-2024)	2.45	1.76	0.684	[0.609, 0.758]	17.960 (394)	0.466	.000
Perceived contribution of LLINs	2.45	1.35	1.102	[0.991, 1.212]	19.582 (393)	−0.194	.000

Similarly, when comparing actual reported malaria cases before the intervention with cases reported in 2024, the average number of cases decreased from 2.45 to 1.76, resulting in a mean reduction of 0.684 cases. This difference was also statistically significant ($t(394) = 17.960$, $p < .001$) with a 95% confidence interval between 0.609 and 0.758, confirming a measurable reduction in malaria incidence after NG-LLIN distribution (Figure 3).

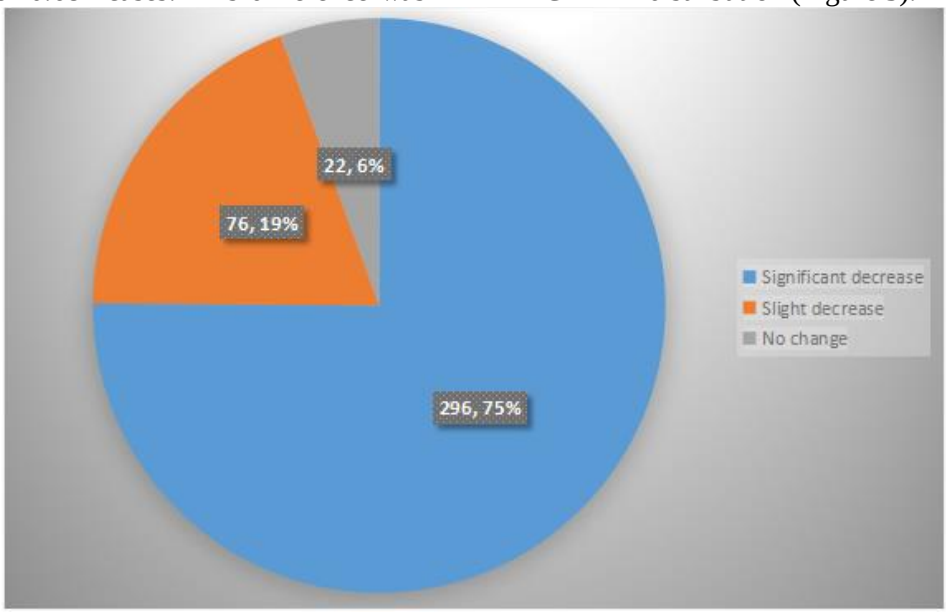


Figure 3. Change in Malaria Cases in Household Since Receiving New Generation LLINs

https://doi.org/10.21522/TIJAR.2014.13.04.Art011

Household-level analysis further illustrated this decline (Table 4; Figure 4). The proportion of households reporting no malaria cases increased from 12.9% before the intervention to 29.9% afterward, while households reporting three to five malaria cases decreased dramatically from 40.5% to 2.8%. Similarly, households reporting more than five cases declined from 8.6% to 1.8% ($p < .001$).

Table 4. Respondents Distribution on the Impact of NG LLINS on Malaria Incidence Prior to and after its Intervention

S/N	Variable	Response Option	Frequency	Percent
1.	Number of malaria cases in household before receiving NG LLINs (2019-2021)	None	51	12.9
		1–2 cases	150	38.0
		3–5 cases	160	40.5
		More than 5 cases	34	8.6
2.	Change in frequency of household malaria-related health facility visits between pre-NG LLIN (2019-2021) and post-NG LLIN (2022-2024) periods	Much less frequently	164	41.5
		Slightly less frequently	197	49.9
		About the same	33	8.4
3	Number of malaria cases in household after receiving NG LLINs (2022–2024)	None	118	29.9
		1–2 cases	259	65.6
		3–5 cases	11	2.8
		More than 5 cases	7	1.8
4.	Reduction in mosquitoes inside sleeping areas since NG LLIN usage began	Yes, a major reduction	251	63.5
		A slight reduction	99	25.1
		No reduction	40	10.1
		More mosquitoes now	5	1.3

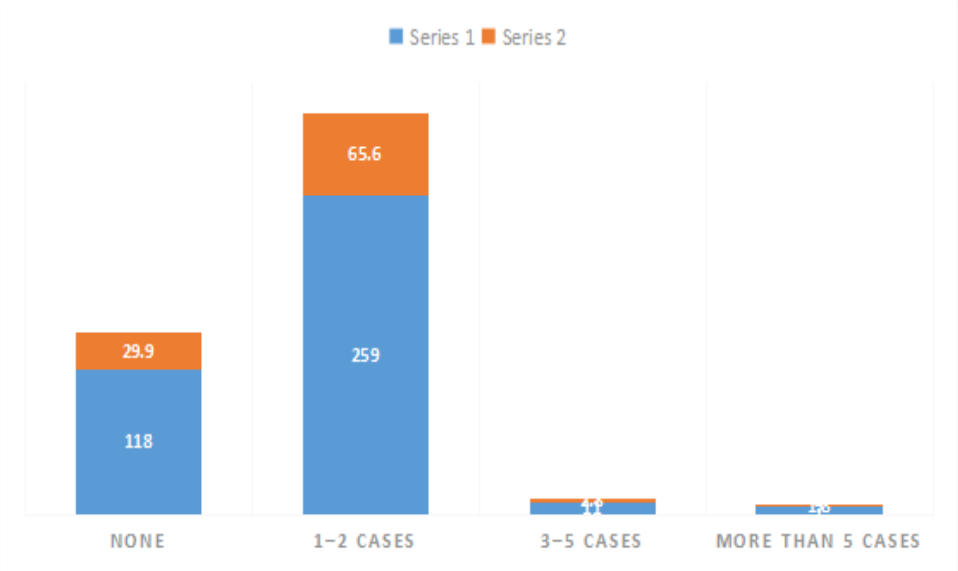


Figure 4. Number of Malaria Cases in Household after Receiving NG LLINs (2022-2024)

Additional analysis showed that longer duration of LLIN use ($p = .004$) and consistent nightly use of the nets ($p = .000$) were significantly associated with lower malaria incidence. These results were further supported by health facility records, which showed a

decline in confirmed malaria cases following the introduction of NG-LLINs, particularly in 2022 and 2023 (Figure 5).

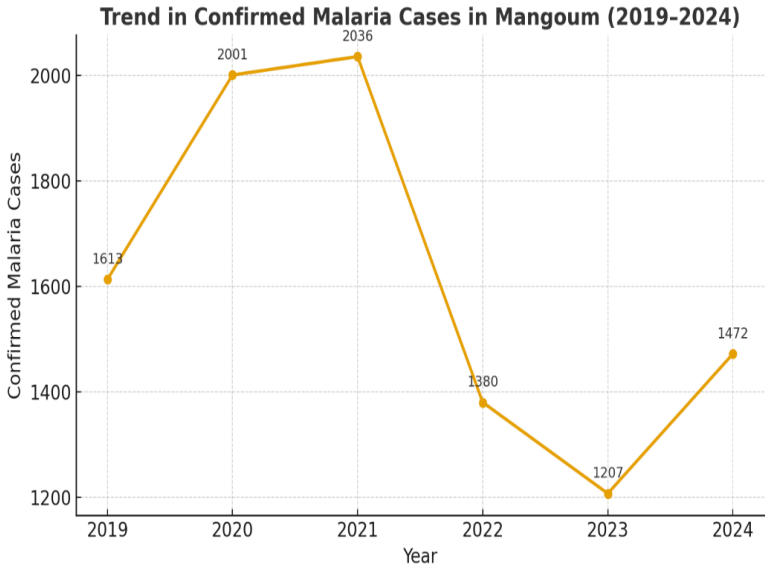


Figure 5. Trend in Confirmed Malaria cases in Mangoum (2019-2024)

Overall, the convergence of household survey data, statistical analysis, and facility records provides strong epidemiological evidence that the distribution and sustained use of new-generation LLINs significantly reduced malaria incidence in Mangoum, Foumbot.

Discussion

Community Uptake and Utilization of New-Generation LLINs

The study found that community uptake and utilization of new-generation LLINs (NG-LLINs) in Mangoum, Foumbot, was high, with over 68% of households reporting net use and nightly usage exceeding 80%. Households that received multiple nets reported higher consistent use, indicating that adequate household coverage is a key determinant of LLIN utilization. This aligns with previous research in sub-Saharan Africa, which has shown that ownership strongly predicts net use, and households with more nets are significantly more likely to use them consistently [14, 18].

Behavioral factors also played a significant role. Households reporting fear of malaria as the primary motivation had the highest nightly net use, whereas male respondents were less likely to use nets consistently. Similar findings have been reported in Tanzania and Uganda, where behavioral and motivational factors were strong predictors of LLIN use [10, 11]. Additionally, the duration of net use, number of people per net, perceived effectiveness, and correct maintenance were significantly associated with utilization, supporting earlier observations that LLIN effectiveness depends not only on distribution but also on household practices and knowledge [16, 5].

Interestingly, neither the year of net distribution nor generalized community beliefs significantly influenced utilization, suggesting that individual household practices and motivation are more critical than temporal or broad community influences. This highlights the importance of ongoing education, behavioral interventions, and follow-up programs to sustain high LLIN usage [18, 11].

Impact of New-Generation LLINs on Malaria Incidence

The introduction of NG-LLINs was associated with a significant reduction in

malaria incidence. Average malaria cases per household decreased from 2.45 before the intervention to 1.30 afterward, and households reporting no malaria cases nearly doubled from 12.9% to 29.9%, while those reporting three to five cases declined sharply from 40.5% to 2.8%. These findings are consistent with cluster-randomized trials in Tanzania and Uganda, where PBO-treated and dual-active LLINs significantly reduced malaria prevalence compared to conventional nets [15-17].

Further, longer duration of net use and consistent nightly use were significantly associated with fewer malaria cases. This corroborates evidence that correct and sustained use of LLINs is vital to achieving malaria control, particularly in areas with high pyrethroid resistance [7, 5]. Households with higher pre-intervention malaria burdens experienced the greatest reductions, supporting the idea that targeted interventions in high-risk populations maximize net effectiveness. Health facility records also reflected a decline in confirmed malaria cases, validating the household survey findings and emphasizing the actual impact of NG-LLINs [12, 4].

The results therefore provide strong epidemiological evidence that NG-LLINs significantly reduce malaria incidence in semi-rural settings, but effectiveness is moderated by behavioral, logistical, and household factors. These findings are consistent with global literature highlighting that LLINs are most effective when combined with community education, proper allocation, and behavioral reinforcement [12, 4].

Conclusion

This study provides strong epidemiological evidence that new-generation long-lasting insecticidal nets (NG-LLINs) significantly reduce malaria incidence at the household level in Mangoum, Foumbot, Cameroon. High community uptake and consistent nightly use were observed, with motivation, net sufficiency, and perceived effectiveness emerging as key determinants of utilization. Households using NG-LLINs experienced substantial reductions in malaria cases, and health facility records confirmed a 40.7% decline in confirmed malaria incidence following net distribution. These findings demonstrate that, beyond distribution, behavioral, logistical, and household factors critically influence the effectiveness of NG-LLIN-based malaria control strategies. Strengthening household coverage, promoting correct and consistent usage, and implementing targeted community education and follow-up programs could further enhance the impact of NG-LLINs. The results offer context-specific evidence to inform national malaria control policies and support the scaling up of new-generation LLIN interventions in similar semi-rural settings where pyrethroid resistance and behavioral barriers challenge malaria prevention efforts.

Conflict of Interest

The authors declare that they have no conflict of interest.

Acknowledgements

I sincerely thank God Almighty for His grace and guidance throughout this doctoral journey. I sincerely appreciate Texila American University, my supervisor, the National Malaria Control Programme, the Mangoum community, and my family, friends, and all who contributed to the successful completion of this study.

Ethical Approval

Ethical approval was obtained from the regional committee for ethics in human health research of the west region. Administrative authorization was obtained from the regional delegation of public health for the west region and the study areas and hospitals. Written informed consent was obtained from all participants before data collection.

Author Contributions

Frida Bessem Taku Bate epse Penda conceived and designed the study, collected the data, performed the statistical analysis, and drafted the manuscript. Innocent Mbulli Ali supervised the study, contributed to the study design, critically reviewed the manuscript, and approved the final version. Eyong Manyiyong Queenta provided technical guidance, reviewed the manuscript. All authors read and approved the final manuscript.

Data Availability

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Funding

The authors received no external funding for this research.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art012

ISSN: 2520-3088
Volume 13 Issue 4, 2026

The UGBC Library's Experiences across the Pre-, During-, and Post-COVID-19 Timelines

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Cite this article as: La Rose, S., Peters, R., & Schwiers, K. The UGBC Library's experiences across the pre-, during-, and post-COVID-19 timelines. Texila Int J Acad Res. 2026;13(4).
https://doi.org/10.21522/TIJAR.2014.13.04.Art012

Article Type: Original Research

Received: 17.07.2026
Accepted: 21.08.2026
Published: 30.10.2026

Abstract *The COVID-19 pandemic resulted in a wave of disruptions worldwide and its effect on the higher education systems significantly impacted their service units, among them being their academic libraries. This study discusses the transformation of the University of Guyana Berbice Campus (UGBC) Library operations and services across three phases: Pre-, During-, and Post-COVID-19 periods. This study utilises a content analysis, a qualitative research approach to discuss the UGBC Library's experience before, during and after the COVID-19 pandemic. Among the findings are that prior to the pandemic, the library was heavily dependent on traditional modes of operations, with the face-to-face services, the physical resources, and integrated minimal digital applications into its operations. In the face of the pandemic, although the abrupt and forced response to remote operations exposed various weaknesses, it also accelerated digital adoption and resulted in forward thinking and innovative work behaviour. During the pandemic timeline, the library first adopted full online operations, then gradually incorporated the hybrid service delivery model, pulling together both the physical and digital service modalities. Library operations in the post covid period can be described as being a continuation of the hybrid service model. The study concludes that despite the challenges brought about by the COVID-19 pandemic, the UGBC Library utilised the experience as an opportunity to transform its services and build greater resilience for the future. Some future recommendations for the UGBC Library include adopting a flexible work schedule, strengthening the hybrid service model, improving ICT infrastructure, and engaging in continuous Professional Development (PD) activities.*

Keywords *Academic Libraries, COVID-19 Pandemic, Lifelong Learning, University of Guyana Berbice Campus Library, Work from Home.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art012

Introduction

Academic libraries are important hubs to their parent institutions, since they provide access to services and resources and support teaching, learning and research.

The University of Guyana Berbice Campus (UGBC) Library was established in 2000 and is an arm of the main Library at the Turkeyen Campus. It provides a range of resources, supporting the teaching and research programmes of the University of Guyana Berbice Campus.

In early 2020, the COVID-19 pandemic affected the way institutions operated and many universities and their support services, like the libraries, closed operations due to the hard lockdowns and social distancing measures. With this, library professionals were forced to find a quick and focused response to transform operations and sustain its services, so as to continue serving its clients. Academic libraries swiftly moved from physical service delivery to entirely digital platforms. This was the impetus for the future of academic libraries.

While this transition was challenging for developing countries like Guyana due to the limitations of its ICT infrastructure, digital inequality and overall limited technological readiness, this did not deter the University of Guyana Berbice Campus Library. The staff at the University of Guyana Berbice Campus (UGBC) began to strategise, in order to continue its operations. The sudden closure of the university in March 2020 was a test for the library in terms of providing its support remotely. This required quick adaptation, innovative delivery methods, while relying heavily on digital technologies.

It must be noted that before the great disruption, the UGBC Library had already introduced initiatives to support various technological modernisation, by firstly implementing Koha Open-Source Library Management System, expanded the electronic information services and further embarked upon minimal digitisation of its materials.

This pandemic accelerated innovative thinking and opened new avenues for the library staff to transform its services, and more importantly, ensure uninterrupted service for its patrons. Some of the initiatives undertaken by the UGBC Library during this wave of COVID-19 were either being introduced for the very first time, or were tasks that existed before, but were now being done with greater intensity. The works executed ranged from verifying book records, facilitating online payments and patron's registration, conducting Information Literacy (IL) sessions using virtual platforms, designing virtual exhibitions and library tours, among other initiatives.

Then emerged the post COVID period of the hybrid service model where operations remained in a dual mode and continuous efforts were made to strengthen the library's digital infrastructure.

This study discusses the UGBC Library's experience during the COVID-19 phases, that is, pre, during and post timelines. It highlights the library's operations before the pandemic, the responses taken by the library during the pandemic and the challenges encountered as well as the transformation of the library's operations and services after the crisis.

The findings from this study provides valuable insights into technological adaptation, organisational resilience, and the future of academic libraries in developing countries. It can also be a support for future crisis preparedness for sustainable library services in this digital era. Further, it can contribute meaningfully to the body of scholarly literature, providing evidence for research in the future.

Objectives

The objectives of this study are to:

1. Identify the operational and technological characteristics of the UGBC Library during the Pre-COVID-19 phase.
2. Discuss the responses and service adaptations implemented by the UGBC

Library during the COVID-19.
3. Investigate the challenges experienced by the UGBC Library during COVID-19.
4. Assess the transformation of the UGBC Library services and operations post COVID-19 phase.

Theoretical Framework

The theoretical model underpinning this research was the resilience theory, the social innovation typology model and the technology acceptance model (TAM).

Resilience Theory

The resilience theory originated through the work of Norman Garmezy, Emmy Werner, and Ann S. Masten in the 1970s. This theory provides a framework to understand how persons develop strengths and coping mechanisms to overcome challenges and focuses on the importance of protective factors and adaptive processes that promote resilience in persons [1]. The resilience theory basically places emphasis on an organisation's ability to adapt and thus recover from disruptions while maintaining essential functions. This is evident in the actions taken by academic libraries globally, that were forced to quickly modify operations during COVID-19. An abundance of literature has documented the new norm for academic libraries, which was brought on because of the pandemic, ranging from online teaching, hybrid environments and digital policies [2]. Another instance is in the context of the Poland academic libraries where they encountered immediate challenges including the lack of relevant benchmarks for service delivery and the absence of universal guides for safety and procedures for COVID-19 [3]. Nevertheless, the Poland academic libraries adjusted well by digitising their collections, expanded infrastructure and increased the online resources [3].

Social Innovation Typology Model

Another model that is applicable at this juncture is the social Innovation typology model, with the leading proponent being Frances Westley, the category of emergency response, and understanding how social innovation occurs. Its important to note how new ideas, services and practices create value especially when existing systems cannot serve any longer [4]. The relevance of this theory is that in the context of libraries, it explains the new ways of service delivery.

Technology Acceptance Model (TAM)

Finally, the TAM theory model, also referred to the individual's adaptation but with a focus on new technologies [5]. This model suggests that the adoption of technology is influenced mainly by perceived ease of use and perceived usefulness. During the COVID-19 period, both library professionals and users were required to engage with digital platforms, electronic databases, online catalogues, and virtual communication systems. TAM provides a useful framework for understanding how the stakeholders of academic libraries adapted to increased reliance on technology.

Together, the resilience, social innovation typology model and TAM theories provide a framework for understanding both technological adaptation and institutional responses to a crisis.

Methodology

The study utilised a qualitative research approach in the form of a content analysis, discussing the experience of an academic library experience before, during and after the COVID-19 pandemic. The content analysis approach was chosen for its sustainability in analysing the UGBC Library’s experience within the pandemic phases. The data were gathered from institutional reports and other relevant materials within the time period. The researchers' lived experiences further served as the primary source of data.

Additionally, scholarly articles retrieved from various academic databases and websites including EBSCOhost, JSTOR, ResearchGate,

Google Scholar, among others, were used to support the study. The combinations of search terms that were used to gather scholarly articles include "academic libraries", "pre-COVID", "during COVID", "post-COVID", "university libraries response to the pandemic". The results obtained from the search were filtered based on full-text, publication year, and subject area which provided about 36 scholarly articles for analysing.

A thematic analysis was conducted after reviewing the documents, resulting in a number of sub-themes, with the three major themes being:

1. Pre-COVID-19 Phase (before 2020): UGBC Library Operations before COVID
2. During COVID-19 Phase (2020-2021): COVID-19, A Disruptive Force Leading to WFH
3. Post-COVID-19 Phase (2022-Present): Transformation of the Library Operations & Services

Findings & Discussion

Analysis of the literature revealed that the pandemic served as a catalyst for accelerated transformations in the library sector. The findings also revealed that although the library experienced some technological readiness before the pandemic, the encountering of significant challenges prompted rapid innovative thinking that transformed service delivery.

Pre-COVID-19 Phase: UGBC Library Operations before COVID

Library Resources and Collection Development

Before the pandemic, one of the UGBC library's primary focus was acquiring, organising and disseminating physical and electronic information resources. The collection development efforts focused on supporting teaching, learning, and research activities across the university programmes. Highlights were usually focused on the growth in print collections, databases, and efforts to improve access to scholarly materials within the Caribbean.

Further, the literature also suggested that academic libraries in the less developed countries were gradually incorporating digital resources before the pandemic, although physical collections remained the central to the services. Academic libraries in Africa, since the pre covid period, were already expanding digital resources, research support, and their technological enabled services, but the pandemic accelerated these developments [6]. Closer home, UWI's St. Augustine Theses collection was digitised and there was also a small but growing e-book Caribbean Collection through the EBSCOhost database etc [7]. Likewise, as also experienced by UGBC Library, UWI would have accelerated work and expanded what existed from the onset of Covid.

Notably, educators in various African universities utilised innovative methods including Web 2.0 applications, repositories, databases, mobile websites, professional development among others in an effort to transform academic libraries in the three stages of global revolutions (pre, post and current COVID-19 eras) [6]. This indication has strengthened the case of an innovative operation mode of institutions, even before the crisis, and continuing after.

On the contrary though, and of interest is for the lock down phase, readings show that universities in Nigeria did not provide online resources to support their parent institutions' online executions [6]. Further, for developed countries, this was not the same [6]. From the researchers' point of view, it is difficult to comprehend, however, this revelation again solidifies the case of another instance of the technology gap and challenges.

Physical Library Services & Operations

The pre-COVID period is widely characterised with services being mostly delivered through face-to-face interactions. At

UGBC Library, these services included:

1. Borrowing & Returning of Materials
2. Renewals
3. Equipment Loans and Miscellaneous Loans
4. Reservation
5. Library Instruction and Tours
6. Reprographic (Printing, Photocopying, Scanning & Binding)
7. Inter-Library Loan
8. Registration & Clearance of patrons
9. Photography & Videography
10. References & Information Literacy Sessions
11. Library's Online Public Access Catalogue and Electronic Resources
12. Social Networking

At UWI during the Pre COVID-19 period, in person photocopies of materials were done or the other option was to photograph the materials using mobile devices [7]. Further based on personal experience of their operations, they also offered reference assistance, reader advisory, circulation and printing services, information literacy training and research topic guidance as their services pre COVID.

Information and Communication Technology Infrastructure

It is important to note that the use of technology and providing virtual assistance are nothing new for the UGBC Library operations, our Head campus library and many other libraries as a whole. This statement is supported by The NMC Horizon Report Summary 2017 Library Edition which indicated that technological applications as they emerge is certainly not new for academic libraries [8].

At the UGBC Library, prior to the emergence of the pandemic, the library utilised various forms of technology to interact and serve its patrons. There was the use of the landline telephone, fax and email as means of interacting with patrons and vendors. Subsequently, a Facebook account was established to connect with the library, thereafter, Twitter and Instagram were also introduced as other platforms. As time progressed and more internet of things (IOT) became available, the Library introduced a mobile phone service with the call and SMS feature only, then in 2016 transitioned to the use of WhatsApp.

The Library also offered other aspects of online services, providing patrons with access to a wide range of subscribed electronic databases. Additionally, in 2011 in collaboration with the Turkeyen Campus Library, the Koha, an Open-Source Library Management System was launched. This represented one of the most significant technological steps taken before the pandemic. Koha significantly improved the cataloguing procedures, circulation management, and resource discovery.

In terms of social media, its use in academic libraries was widespread, but it was more for the basic and informational purposes, focusing on outreach rather than interactive or for heavy service engagement [9].

A study of university libraries in Asia, North America and Europe found that 71.1% of libraries participated already used social networking tools with Facebook and Twitter being the most widely adopted [10]. This in itself shows the relevance and importance of social media even before COVID-19.

Our Caribbean counterparts at UWI were also positioned to use technology that ranged from institutional repository and UWIlinC an information portal with information resources including the university's intellectual output, electronic resources (journals, databases, books) and the catalogues for all UWI campuses. The Mona Online Research Database (MORD) comprised faculty research but with specific emphasis on HIV/AID [11]. Further, Facebook, Twitter, YouTube Flickr have all been introduced and in use at UWI [12].

These initial developments were merely intended to improve operational efficiency rather than prepare the library for a global crisis. Nevertheless, in particular the automated systems and Web 2.0 applications became crucial once physical operations were disrupted. Therefore, in this case it can be seen that technological investments prove beneficial beyond their original purpose. A mere routine modernisation effort before 2020 became a very essential component of the library's emergency response strategy during the pandemic and continuing to the present day.

Opportunities and Challenges Pre- COVID-19

While the UGBC Library succeeded in staff development initiatives, expanded its collection, engaged in collaboration both internally and externally, challenges did not spare our territory. These challenges included limited funding for technological projects, lack of ICT infrastructure, and growing demands for various electronic databases and subscription services.

Likewise, with technological advancement, there has been an increase in published works, and this compelled information professionals and modern libraries to pursue and adopt these modern digital tools and procedures in carrying out its activities [13]. For example, libraries have adopted electronic devices and methods in its service delivery including the Online Public Access Catalogue (OPAC) for cataloguing and online searches, electronic devices for browsing and emails for registration, among others [13].

Additionally, a study revealed that the libraries investigated were delivering their services with functional library buildings, however, their collection varies and there is inadequate staffing [14]. The study further highlighted that many of the libraries lack collection development policies, the non-book materials are very meagre, digitisation of collections are not widely adopted, and as such it's critical to strengthen service delivery and increase staffing [14].

During COVID-19 Phase: COVID-19, A Disruptive Force Leading to Exclusive WFH then Phased Re-Opening/Blended Modes

During the COVID-19 pandemic, there were two (2) modes of operations at the UGBC Library namely: Telework/Remote Work/WFH (March 26 -September 4, 2020) and Blended Modes (September 7, 2020-April 29, 2022) (see Figure 1 below).

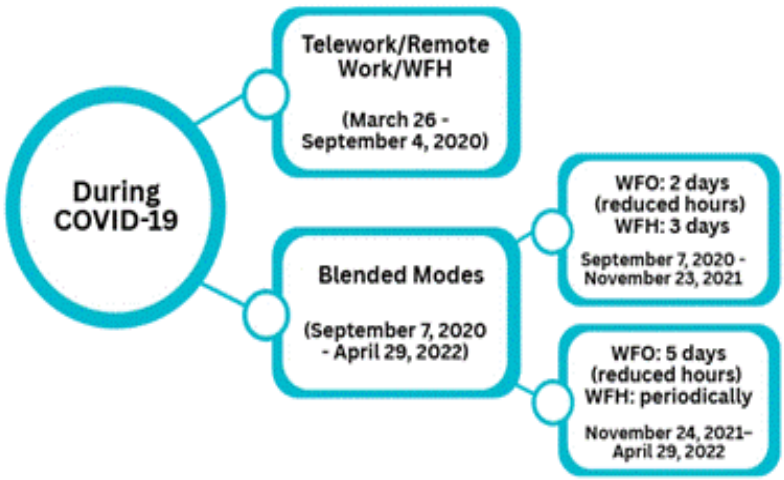


Figure 1. UGBC Library Operation Modes During the COVID-19 Pandemic

Adapted from Ref. [15].

Telework/Remote Work/WFH in Brief

The practice of telework, remote work or work from home was forced upon us and made more popular due to the COVID-19 pandemic. However, it is important to note that this concept is not new. In 1972, Jack Niles, a NASA engineer coined the term telecommuting since he was working from home on a complex communication system [16]. The growth of WFH in the pre-pandemic period was a viable option owing to the advancement of technology. Although Video-call software (Teams, Zoom, Webex), cloud file-sharing packages (Box, Drive, Dropbox) and connectivity software (Asana, Gmail and Slack) were widely available in 2019, are essentials for remote work but were not in existence during 2000, hence working remotely was executed by utilising telephone and emails at that time [17].

However, at the UGBC Library, during the pre-pandemic era, although the telephone, emails and the web 2.0 technologies existed there was no official mandate in terms of working from home. But from time to time, staff would engage in working from their homes in order to complete tasks to meet deadlines etc. This was, however, not under an official capacity, since this feature was never a practice here.

In general, there was some amount of growth in remote work, however, the COVID-19 pandemic resulted in the drastic push towards this growth, making it official. As is evident, the work from home initiative is nothing new, and was referred to by various titles. In the early years home-based jobs were in agriculture or the craft, however, in 1965 around 0.4% of full paid days in the US were WFH, then by the 1990s the WFH rapidly increased in the United States, due to the advancement in information and communication technology [17]. As personal computers became common, by the 1990s the WFH in the US doubled, and kept increasing as the internet became widely available [17]. However, with the pandemic and with this arrangement being forced upon us, organisations adopted, then adapted, and this quickly became the order of the day. In the beginning of the pandemic, remote work was made an option for all staff irrespective of their roles [18]. Further, for some, it meant an adjustment in the type of task they performed, i.e. shifting from a service desk to a chat service [18].

For online stores, call centres and teaching staff, the WFH/Telework/Telecommuting is readily visible. The recurring question that information professionals often faced during this pandemic period were “what really would WFH entail?”. Some people thought that WFH meant sitting on the couch, watching TV, with the laptop lying nearby, however, that was not the case because there is a desk, monitor, post-it notes and all other necessary materials set up to execute work [19].

In giving some explanation for the above discussion, it must be noted that for information services or libraries, this WFH was repeatedly questioned, given that information resources and the entire internet are already accessible remotely, - what value can library or information services professionals be engaged in or continue to provide?

Generally, library activities range from virtual reference and other enquiries, ordering and requesting invoices, locating vendors and materials, social media outreach, online document delivery, demonstrating the use of online resources, convening meetings etc., and these have definitely ensured that information services have secured a place and with no more guessing, easily fits into Telework. It must be noted that some jobs are more appropriate for telework such as engaging in indexing and cataloguing, working on websites, creating aids for patrons, facilitating virtual reference, among others [20].

Initiation of WFH at the UGBC Library

With the lockdown at UG on March 16, 2020 which was anticipated for only a few days, the administration made arrangements for the way forward. Some staff at UGBCL continued to be available, engaging with the basics of its services i.e. answering queries from patrons, extending due dates for items etc. via the usual virtual mode of operations, e.g. using social media, emails and WhatsApp. With the reality of the shutdown no longer being a few days, staff commenced utilising the staff's WhatsApp group more frequently. At this point an engagement ensued on the way forward, for our mission resulting in the grab work -take home initiative. It must be noted that this proved to be a great way for collaborating and to serve our patrons. One librarian mentioned that following the pandemic, a WhatsApp group was created by the library management to post updates, share views on providing library service, and also engage in sharing words of encouragement; it was then that they discovered that WhatsApp is a great tool that can be used in service delivery [21]. Likewise, the UGBC Library staff, with pride supports this sentiment that indeed, during the lockdown, we also discovered the great advantage of the WhatsApp tool and appreciated the same.

With the UG's lock down orders in effect, on March 26, 2020, UGBC Library staff visited the Library to retrieve selected Library assets in order to be able to work from home. The work tasks were divided among the staff and those who chose not to visit the Library, their work materials were packaged and placed at the security hut for pick up, while others were delivered to those staff in nearby residences [15]. What is interesting is one library professional with only four months on the job, indicated that before she left on the day of the lockdown, she took materials which required original cataloguing and her laptop in order to continue her work at home [23]. In another instance, another library professional noted that after work from home emerged, the staff decided to creep back into the library and grab items such as books, puppets, and others that are necessary for programmes like virtual story times, etc. These collaborative efforts demonstrate that library professionals were ready and willing to beat the odds in order to continue providing services.

During the WFH period, the UGBC Library staff used a variety of spaces including hammocks, sofas, in the kitchen area and even some set up designated office spaces, with work activity durations often extending into the evenings [15]. Many transformed these sections of their homes into their work environments in order to be of service to patrons. Similarly, working remotely, from various locations at home e.g. from backyard to garages, resulted in staff being in new virtual spaces, away from the library building [23].

For the UGBC Library staff, they were indeed in this new virtual space away from their physical offices, commencing duties early in the mornings with late night endings, and at the same time enjoying the benefits of the forced work from home experience. The WFH initiatives resulted in staff members completing the following tasks [15]:

1. Verified catalogue card records
2. Cleaned and organised files and folders on flash drives
3. Sorted and uploaded files and folders on cloud storage
4. Organised, classified and labelled photography and videography projects in hard drives
5. Prepared books for repairs
6. Cleared patrons using the tray with registration cards
7. Listed old Reading Room tickets
8. Transformed ledgers to the soft copy format, this is referred to as our green projects where all information in the accession ledger, staff research ledger and clearance ledger were manually digitised (typed) and stored on the cloud

9. Scanned accession slips and examination papers
10. Engaged in administrative tasks including report preparation, following-up on vendors, planning for reopening, etc.
11. Attended meetings, seminars, workshops and training sessions
12. Explored open access sites
13. Catalogued materials
14. Fulfilled patrons' requests thru digital platforms for articles following copyright guidelines
15. Promoted the use of the IL trainings, accessing our databases, & open educational resources
16. Created virtual tours, exhibitions and instructional guides.
17. Conducted IL sessions via digital platforms
18. Responded to patron inquiries
19. Retrieving relevant newspaper clippings
20. Collaborated with overseas colleagues for assistance in fulfilling patrons' requests.
21. Assessed the status of the workplan and added new areas where necessary
22. Assisted patrons with various research needs: referencing, editorial work, etc.

On reflecting upon other literature, it was found that an information professional commenced work at 9:30 in the morning with status updates, cataloguing work, procuring materials and working towards building a digital collection [22]. Additionally, during the initial stages of the outbreak, library staff engaged in professional development activities, focused on social media engagement, conducted administrative tasks, built the collection and prepared for the reopening of the library [18]. Further, library staff working from home were expected to provide updates pertaining to the tasks and services they provided to the senior management [21]. It is important to note that during this time, communication was important since some persons were new to some tasks and needed guidance. In terms of this communication, in the face-to-face operational mode, persons could have engaged in direct and immediate interactions which promote a better understanding and more effective communication than the virtual mode due to disruptions from the internet, etc.

Extensive Use of Virtual Services

Virtual services at the UGBC Library are nothing new. However, in order to make patrons aware that the library was still strictly serving from home during the lockdown, notices were created indicating that while the physical doors were closed, the library was still open to serve its patrons. These notices quickly became the library's WhatsApp status and were featured on all its social media platforms. Libraries in their quest to reach out to their patrons utilise various means where information and communication technologies (ICTs) tools become useful for delivering services during the lockdown [21]. For instance, although libraries were closed, librarians at Northeastern Illinois University (NEIU) continued to assist students via email and zoom sessions [24].

At UGBC Library, our virtual services became increasingly demanding and therefore, major attention had to be given to this service. Patrons were bombarding us for hardcover books from the collection but because of the Campus being off limits, this was not possible. Notably too, these requests were received at all hours of the 24-hr. day period via social media platforms, emails, chat, WhatsApp, SMS, and calls. To fulfil the requests, staff members began searching the library's available databases like EBSCO host, JSTOR, Research4Life, etc., to find an article or the entire book or journal of exactly what was requested or appropriate alternatives. This was then sent to the patron electronically. The libraries' role should be highly valued during the COVID-19 pandemic due to the increase in provision of quality databases such as JSTOR, PubMed, ERIC, etc. which bridged the gap in

relation to gaining access to scholarly materials [21]. In addition, library staff continued to fulfil requests for articles and book chapters through interlibrary loan and document delivery as well as reference and instruction via Google Meet, email, chat, and phone [24]. Moreover, library staff while working from home were handling queries online pertaining to providing books, articles, among others [25]. Further, other library staff highlighted that they were providing 24/7 service which includes providing open digital contents, books/articles, responding to queries, updating the library's websites, among others via email, WhatsApp and phone to accommodate patrons [25]. The intense searches by the UGBC Library staff in the pursuit of finding digital copy matches for the patrons' requests, resulted in us discovering many free/open sites as well as organisations who had generously made their scholarly materials available at no cost.

During the pandemic many vendors provided open access to some of their academic resources [25]. Further, to ensure the delivery and sustenance of the service, staff even reached out to colleagues at other overseas universities in order to ascertain if access could be given to some materials that were not available from the UGBC Library staff searches. Overall, it's important to note that patrons appreciated the efforts of the UGBC Library staff in fulfilling their requests and as such would leave comments on various platforms like "very helpful", "love the instant feedback", among others.

Promoting the services at the UGBC Library, was also done via social media platforms, in this case, by creating step by step instructional ads/guides on database usage and how to recognise scholarly work, among others. One librarian highlighted that during the pandemic, several librarians from their team created mini-instructional videos, demonstrating how to evaluate online information, among others; and these videos were easily accessible to students via social media [22].

Further, numerous IL sessions were conducted (both by whole class & one-on-one sessions), focusing on plagiarism, referencing materials, identifying credible sources, utilising the various databases, etc. using various methods of delivery. Research assistance was also given to patrons which entailed editorial works, formatting of papers, among others.

Other virtual services provided by the UGBC Library included clearances, exhibitions, library tours, etc. Interestingly, there are mixed views on library operations, for example, the pandemic just accelerated the trends for which already existed rather than created entirely new ones [26]. However, this may not be entirely true to be used as a generalised statement since for example, UGBC Library introduced for the first time virtual library tours, exhibitions and web conferencing tools for the IL training following the pandemic.

Blended Modes

This mode was done in two phases (see Figure 1 on page 9) with all health and safety precaution measures in place.

- **Phase 1 -** Work from Office (WFO) 2 days with reduced hours & Work from Home (WFH) 3 days & more per week.
- **Phase 2 -** WFO: 5 days per week with reduced hours & WFH –periodically.

During this mode of operation, the UGBC Library staff engaged in the following tasks:

- **WFO:** Digitised materials that were in demand including examination papers, catalogued materials, quarantined materials, offered reprographic and circulation services.
- **WFH:** Fulfilled request for materials, responded to queries, edited photographs, conducted social media outreaches and gave IL assistance.

Opportunities Emerging from WFH Due to the Lockdown

While there are many benefits reported by other researchers regarding WFH, there are four major aspects from the UGBC Library experience [15].

Firstly, Library staff were given the opportunity to complete projects that were previously on hold due to competing work demands. It is quite interesting to note too that at the UGBC Library, certain projects that were previously overlooked, such as digitising of accession slips, ledgers, backing up files on cloud storage as well as organising photographs and video recordings regarding UG matters, were all worked on during this period. Similarly, one librarian pointed out that teleworking was considered a blessing in disguise since it gives her time she always wanted but never had until now [22]. Further, she was able to focus on commencing and completing projects like cleaning up catalogue and repository records, converting hundreds of files from one of the earliest digitised special collections, among others [22].

Secondly, there was a shift in focus, for example, to digitise examination papers since a void in this work activity was discovered. Particularly, there were overwhelming requests for past examination papers which were only stored in the hard copy format. At this point it was clear that UGBC Library was indeed digitising information as we referred to it as the green projects. However, the examination papers were not yet done and subsequently had to be given priority because of the increasing demand. The fact was that indeed UGBC Library initiatives included digitising materials using traditional means, however, the question was what items were given the priority. As noted by D. Cort (personal communication, February 10, 2020), digitising of materials indeed might for some only be commencing now- (due to the pandemic), however, other libraries would have been digitising information long before the crisis, but the question is what resources precisely were being digitised by the latter? From a Pakistani standpoint, patrons from the social sciences and humanities required more library support since information relating to their subject areas were mostly available in printed formats at the university libraries [25]. There is a need for digitisation of both print and special collections because in the future there will be the need to shift digitised content from a preservation/review tool, to becoming the point of access to the collection [25]. For many, the COVID-19 pandemic must be credited to paving the way and making essential print materials now readily accessible via the virtual platforms and not just for preservation purposes, something that the UGBC Library can relate to.

Thirdly, for the first time, the UGBC Library staff undertook the WFH approach and the experience indicated that it provided a balance between work and home duties due to the flexible work schedule. It is interesting to note that for some staff, this working from home enhanced their output [18]. For some staff at the UGBC Library, it indeed had a positive impact on their productivity in terms of completing tasks that were overlooked due to demanding normal onsite work routines, as was evident in their reports/statistics submitted. In terms of providing evidence of positive productivity levels discussed herein, Table 1 presents these outcomes.

Table 1. Comparison of Some Statistics: Pre-exclusive WFH Period vs Exclusive WFH Period (For the 5 Months Duration)

Activities/Tasks	**Pre-exclusive WFH (March 26-Sept 4, 2019)**	**Exclusive WFH (March 26-Sept 4, 2020)**
Records verified	251	1362
Catalogued e-resources	41	143

Located E-resources for patrons' access	NIL	537

Finally, the UGBC Library staff worked across assigned duties. For example, the book binder, although not practically being able to the binding equipment, she nevertheless assisted with some of the tasks like verification of catalogue cards and digitising of materials which were normally performed by the Library Assistants. Additionally, the UGBC Library staff engaged in PD activities to improve service delivery due to the setback caused by the pandemic [15]. For instance, when technical difficulties are experienced by the UGBC Library staff, they would solicit the services of the technicians, to rectify the problem. However, due to the isolation and the urge to get work done, staff willingly participated in and completed short courses or utilised the trial by error option in order to rectify these problems. As library staff adapted to remote working, they spent more time on professional development and took advantage of learning opportunities online; this is evident in a poll at an Online Computer Library Center (OCLC) virtual town hall where 81% of the respondents reported an upward trend in their participation with professional development opportunities since the start of the pandemic [27]. At the UGBC Library every professional development opportunity that was provided by the administration and others, staff were always ready to take the opportunity. Of interest to note is that some staff who were considered the traditional type, were resistant to change and did not want to use the collaboration tools like Google Docs, were forced to incorporate the same into their routine, and now cannot envision themselves not continuing with it. During the pandemic, some staff refreshed their knowledge of existing procedures while others developed new skills, and this is reflected in preceding sections of this discussion [15]. Likewise, one of the opportunities for academic libraries was technology acceleration, especially as it relates to Artificial Intelligence such as the BOT introduction etc [28]. It's important also to highlight here that some staff perform duties beyond their designated roles, willingly taking up the challenge to learn and work. The staff undertook this for the love of doing what they do and keeping occupied, library counterparts the world over were doing it, and for the obvious - staff felt their obligation to contribute since the library is the support hub for teaching staff.

Challenges Emerging from WFH due to the Lockdown

Aside from the positives that emerged from the lockdown, the UGBC Library encountered four major challenges from this WFH practice [15].

Firstly, there was competition for resources including workspaces, devices, among others within the staff home settings. For example, with families where both parents were working and children were studying, it was a challenge sharing the resources at the same time, resulting in poor internet connectivity, taking turns to use devices, among others. Library staff while working at home periodically experienced bandwidth issues since their partners/children were also having online meetings [29]. For others, lacking resources like the internet prompted them to visit locations other than their home in order to get work done. It is critical to note that for the effective WFH process, staff needed technological tools and internet access [18]. It is an additional cost for libraries to support remote work since internet access, equipment and furnishings are needed [30].

Secondly, the work hours increased for some staff at the UGBC Library since there were increasingly overwhelming requests from patrons which resulted in mental exhaustion and limited self-care. However, other library staff encountered similar issues where they

mentioned that due to providing 24/7 services, the extended work routines add pressure to them [25]. Likewise, many librarians have faced depression/burnout, with varying degrees of intensity due to them being deeply immersed in their daily tasks, thus overlooking the importance of monitoring their own mental well-being [31]. Quite notable is the common trend of working extended hours during the pandemic. This might have been due to the sudden impact of the COVID-19 pandemic where staff felt an increased sense of duty to maintain productivity at all costs. However, amidst this commitment, staff failed to acknowledge the importance of slowing down and taking breaks for self-care. Consequently, this continuous pace led to burnout for many.

Thirdly, some of the library work could not be done offsite. For example, the binder could not have carried the necessary equipment home for binding and book repairs. Another pertinent example relates to the library attendant, whose duties specifically required that the staff be onsite, and further due to lack of internet and other resources, the attendant could not have assisted with other work aspects during this exclusive WFH period. Therefore, her contribution to overall productivity was limited.

Finally, some staff encountered various disruptions (internet and power outage) and also other disturbances from within the family (e.g. children, especially those in online classes), housework, visitors, outside noises, among others while working from home. Similarly, some employees found it challenging to concentrate with family and pets nearby, forcing them to adjust their work hours to late nights or off-peak times when distractions are reduced [23].

Post COVID-19 Phase: Transformation of the Library Operations & Services

Resumption of Library Operations

The UGBC Library began to open gradually, and in-person services were increasingly restored during the post-COVID period. The restoration of physical operations occurred with health and safety measures in place.

The Lauinger Library building and facilities were used but with various restrictions, for example, daily checks and bookings were required before using the campus [32]. Further, the staff were to be vigilant and ensure health and safety guidelines are observed such as wearing of masks, maintaining physical distancing, complying with quarantine requirements, among others [32].

Additionally, some notable strategies that were considered for post-pandemic entails development of human resource, digitisation of resources, adopt flexible work systems and focus on health and wellness of staff and patrons [33].

Adoption of Hybrid Service Models

While the UGBC Library resumed face-to-face operations during the post-COVID period, it adopted a hybrid service model where some of its services including IL sessions (class and one-on-ones), registration, among others were offered both face-to-face and online. This development reflects a broader trend within academic libraries globally. It is evident that the current era, post covid 19, organisations have already been shaped by the crisis and as for academic libraries the operations have been retained continuing in full force.

Libraries now provide services both on campus and online, allowing users to access resources regardless of location [4]. Libraries continue to provide online assistance through Live chat, video consultations (Zoom, Microsoft Teams, Google Meet) SMS and WhatsApp services [34]. Likewise, during the crisis library's role included wellness programmes like mental health and awareness, job search assistance, digital skill training and many of these programs continued in both the virtual and in-person formats [35].

Strengthening of Digital Infrastructure

The UGBC Library in collaboration with the Turkeyen Campus Library continued to invest in electronic resources post-COVID since the University programmes continue to be in blended modes.

Additionally, the UGBC Library in collaboration with the UG's Tactical Online Services (TOS) Unit set up a library zoom account to accommodate IL sessions online since these requests outnumbered the face-to-face ones.

Further, the UGBC Library began working on various technological projects including:

1. Establishing an institutional repository which will make staff and student research works accessible to patrons electronically rather than just physically
2. Using a chatbot for routine queries so that staff could focus on other important projects that were sidelined
3. Developing a website to provide IL support to patrons.
4. The COVID-19 pandemic reinforced the importance of information accessibility and more importantly digital readiness by academic libraries resulting in more emphasis being placed on technology enhancement at the UGBC Library.

Interpretations of Findings Through the Theoretical Framework

Resilience Theory

As it relates to the resilience theory, it can be seen that although the UGBC Library experienced a significant disruption in its services it nevertheless maintained its main function of providing support to the teaching, learning and research at the University of Guyana. The UGBC Library adapted to the changing circumstances by quick thinking, collaboration and technological integration. The UGBC Library's capacity to adapt while continuing to provide its critical services demonstrated the characteristics of a resilient library. Also, the continuation of many innovative projects post pandemic further suggest that resilience is not only recovery but transformational.

Social Innovation Typology Model

The social innovation typology model was used to discuss how the UGBC Library adapted its services pre-COVID, during COVID and post COVID. In the pre-COVID phase, the UGBC Library mainly offered face-to-face services; during COVID, it expanded its access to online resources and virtual support to meet patrons' needs; and the post-COVID period, the library adopted a hybrid service model, strengthen its digital infrastructure and expand its electronic resources.

Technology Acceptance Model

The technology acceptance model is evident at the UGBC Library. For example, in the pre-pandemic period, while digital tools like Google workspaces, zoom, were available, they were not central to everyday library operations. However, during the pandemic, staff increased their reliance on these tools because they were seen as both useful and necessary. Therefore, the acceptance of these digital tools increased as familiarity and use increased. While some of the UGBC Library staff previously preferred traditional tools, their level of comfort increases as their use of the tools increased. Hence, this pattern aligns with the model that proposes that perceived usefulness and ease of use influence the adoption of technology.

Conclusion

With the appropriate theoretical frames integrated, the study discussed the UGBC Library's experiences before, during and after the COVID-19 pandemic by reviewing a number of literatures suggests that while the UGBC Library entered the pandemic with a predominantly traditional service model, prior investments in technology and the ability to adapt quickly paved the way for the transition to remote operations. The role of library

professionals evolved to embrace technologies and the use of other initiatives to remain relevant, capturing the resilience and substance mandate. Resilience resonates with words like ability to survive, adapt, and thrive despite the situation; and this requires commitment, flexibility and quick thinking.

During the COVID-19 phase, the UGBC Library through its initiatives, that is, fulfilling patrons' requests, conducting information literacy sessions, providing research assistance, digitising documents, converting file storage to the cloud, organising photography and videography projects, engaging in administrative work, among others did manage to show through the pandemics our transformation to the sustainable and resilience of libraries. During this period, UGBC Library had the opportunity to complete projects that were side-lined and refocused processes after discovery of various work gaps. Additionally, staff members embraced a flexible work schedule, worked across designated duties, had the opportunity to learn & re-learn, and also engage in professional development opportunities to stay current to effectively deliver job outputs. Amidst the challenges staff experienced during the WFH stint were lack of resources and skills, competition for resources within the home setting, increased workload n hours, burnt out and a variety of disruptions. Periodically, WFH initiative remains high as a recommended adjustment for the future from the staff perspective. Hence to make this possible there is need to adjust work policies and improve technological infrastructure.

In the post-pandemic period, the library adopted a hybrid service model that combines both the traditional face-to-face and digital modes as well as continued to seek ways to strengthen its digital infrastructure.

This study concludes that the COVID-19 pandemic served as a catalyst for digital transformation and emphasised the importance of technological readiness and resilience in academic libraries.

Recommendations

The following recommendations are made for the UGBC Library based on the findings of the study.

1. **Adopt a flexible work schedule:** Consideration can be given to the implementation of aspects of administrative work to fit a blended mode and a flexible work schedule supporting work and home life balance. Likewise, staff who had experienced working from home during the pandemic shared similar sentiments. For example, the results of the 2020 State of Remote Work revealed that 98% of persons expressed their interest to continue working remotely for the remaining of their lives, however, he emphasised that for remote work to be new norm, changes have to be made to the work culture [36].
2. **Strengthen its hybrid service models:** The UGBC Library should provide more of its services to its patrons using a hybrid mode, that is, both face-to-face and via various social media platforms, zoom, emails, chats, WhatsApp, SMS, calls, etc.
3. **Develop crisis management plans**: In order to adapt to the changing library environment brought on by the advancement of technology and natural disasters like the pandemic, academic libraries including the UGBC Library should have plans and policies in place.
4. **Improve its ICT infrastructure:** The UGBC Library should invest in more ICT infrastructure to support hybrid service models.
5. **Continue to expand its electronic resources:** The UGBC Library should increase its database subscriptions and build its digital collections to better serve its patrons evolving needs.
6. **Engage in professional development**

activities: The UGBC Library should expose its staff to ongoing PD sessions in order to keep up with this constantly changing environment.

Conflict of Interest

There was no conflict of interest.

Acknowledgements

The authors would like to express heartfelt gratitude to Mr. P. DaSilva for his constructive feedback on this research.

Ethical Approval

The University of Guyana Research Ethics Board has accorded exemption for this research.

Authors' Contribution

All authors contributed equally to this research.

Funding

This research was conducted without any external funding.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art013

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Temporal Trends and Geographic Variation in Multiple Micronutrient Supplementation Implementation Performance in Ethiopia: A Routine Monitoring Data Analysis, 2023–2026

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Cite this article as: Abnet Tesfaye Kebede. Temporal Trends and Geographic Variation in Multiple Micronutrient Supplementation Implementation Performance in Ethiopia: A Routine Monitoring Data Analysis, 2023-2026. Texila Int J Acad Res. 2026;13(4).
https://doi.org/10.21522/TIJAR.2014.13.04.Art013

Article Type: Original Research

Received: 08.09.2026

Accepted: 06.10.2026

Published: 30.10.2026

Abstract *Maternal micronutrient deficiencies remain an important public health challenge in Ethiopia and contribute to adverse maternal and newborn outcomes. Ethiopia introduced Multiple Micronutrient Supplementation (MMS) through routine antenatal care services and progressively expanded implementation from 21 pilot woredas in 2023–2024 to 80 woredas nationwide by 2026. However, evidence on implementation performance during national scale-up remains limited. This study assessed temporal trends and geographic variation in MMS implementation performance using routine program monitoring data collected between January 2023 and June 2026. A longitudinal secondary analysis was conducted using woreda-month observations from the national MMS monitoring database. MMS achievement was defined as the percentage of pregnant women newly supplemented with MMS relative to the monthly target. Descriptive and non-parametric statistical analyses were applied. The final analytical dataset included 2,268 unique woreda-month observations of which 1,724 (76.0%) had available MMS achievement data. Mean MMS achievement was 100.2% (SD 56.3), while the median was 94.6% (IQR 70.5–120.4). Median achievement declined from 98.8% during 2023–2024 to 93.2% in 2025 and 89.9% in 2026. Existing woredas achieved higher median performance than Expansion woredas (96.4% vs. 85.3%; $p<0.001$). Significant regional variation was observed, with median achievement ranging from 64.1% in Somali to 102.0% in Oromia and Dire Dawa. Reporting completeness declined substantially during scale-up. MMS implementation remained broadly aligned with program targets but varied across regions and implementation settings, highlighting the need for strong implementation support, monitoring systems, and data-quality assurance during national expansion.*

Keywords *Ethiopia, Geographic Variation, Implementation Performance, Maternal Nutrition, Multiple Micronutrient Supplementation, Routine Monitoring, Temporal Trends.*

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Introduction

Maternal micronutrient deficiencies remain a major public health concern in low- and middle-income countries and are associated with adverse maternal and newborn outcomes, including anemia, preterm birth, low birth weight, fetal growth restriction, and neonatal mortality. Despite improvements in maternal health services, maternal undernutrition and micronutrient deficiencies continue to contribute substantially to the burden of maternal and newborn morbidity in Ethiopia. National survey findings indicate persistent nutritional challenges and regional disparities in maternal health service utilization across the country [16, 17].

Iron and folic acid (IFA) supplementation has long been the standard antenatal nutrition intervention for preventing maternal anemia and neural tube defects. However, evidence from systematic reviews and meta-analyses indicates that Multiple Micronutrient Supplementation (MMS), which contains iron, folic acid, and additional essential vitamins and minerals, provides greater benefits than IFA alone, including reductions in low birth weight, small-for-gestational-age births, and preterm delivery [2-8, 15]. Consequently, MMS is increasingly recognized as an effective strategy for improving maternal nutrition and birth outcomes in settings characterized by multiple micronutrient deficiencies [16, 17].

Ethiopia introduced MMS through routine antenatal care services using a phased implementation approach. The program began in 21 pilot woredas across five regions during 2023-2024 and expanded nationally to 75 woredas in 2025 and 80 woredas in 2026 [9, 12]. Scale-up activities included health worker training, supportive supervision, social and behavior change interventions, community engagement, routine performance monitoring, and supply-chain strengthening [18, 19].

As implementation expanded across diverse geographic and health-system contexts, understanding program performance became increasingly important for informing policy and operational decision-making. Differences in health-system capacity, commodity availability, reporting systems, supervision, and community engagement may influence MMS implementation performance across regions and implementation settings. Although routine monitoring systems provide valuable opportunities to assess implementation performance during scale-up, evidence describing temporal trends and geographic variation in MMS implementation performance in Ethiopia remains limited. Generating such evidence is important for identifying areas requiring additional implementation support and for informing equitable national scale-up.

International agencies, including WHO, UNICEF, Nutrition International, and the Children's Investment Fund Foundation (CIFF), increasingly support MMS implementation and scale-up efforts globally [1, 9, 11].

Study Objective

This study aimed to assess temporal trends and geographic variation in Multiple Micronutrient Supplementation implementation performance in Ethiopia using routine program monitoring data collected between January 2023 and June 2026.

Methods

Study Design

A longitudinal secondary analysis of routine MMS program monitoring data was conducted using reports submitted from implementation woredas between January 2023 and June 2026.

Study Setting

The study was conducted in Ethiopia. MMS implementation began in 21 pilot woredas across five regions (Oromia, SNNP, Sidama, Somali, and Gambella) during 2023–2024. The program expanded nationally to 75 woredas in 2025 and 80 woredas in 2026.

https://doi.org/10.21522/TIJAR.2014.13.04.Art013

Data Source

Data were obtained from the national MMS routine monitoring database. Monthly reports included information on MMS achievement, supply availability, supportive supervision, health worker training, community engagement activities, and other implementation indicators routinely collected through the national MMS monitoring system.

Unit of Analysis

The unit of analysis was the woreda-month observation. The routine MMS monitoring database initially contained 2,820 records. Following data cleaning, removal of duplicate observations, and exclusion of multiple submissions for the same woreda-month reporting period, the final analytical dataset comprised 2,268 unique woreda-month observations. The process of data cleaning, record selection, duplicate removal, and derivation of the final analytical dataset is illustrated in Figure 1.

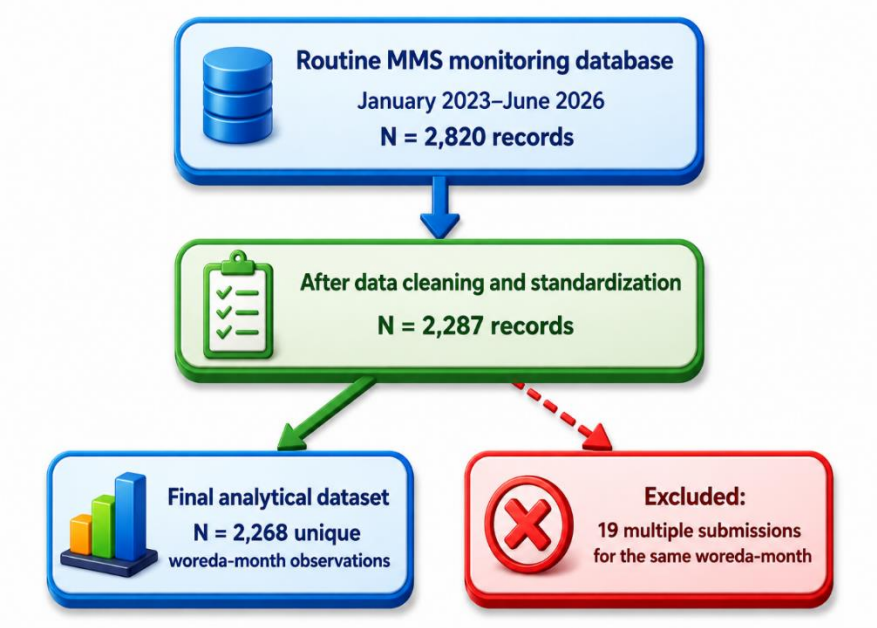


Figure 1. Flow diagram of Routine MMS Monitoring Data Processing and Selection of the Final Analytical Dataset, Ethiopia, January 2023-June 2026

Outcome Variable

MMS achievement was calculated as:

$$\text{MMS Achievement (\%)} = \frac{\text{Number of pregnant women newly supplemented with MMS}}{\text{Monthly target number of pregnant women}} \times 100$$

Observations with missing or zero monthly targets were excluded from MMS achievement calculations. Values exceeding 100% were retained because achievement represents performance relative to reported program targets rather than population coverage.

Statistical Analysis

Descriptive analyses were conducted to summarize dataset characteristics, MMS achievement, temporal trends, geographic variation, and data completeness. Continuous variables were described using means, standard deviations, medians, interquartile ranges (IQRs), minimums, and maximums, whereas categorical variables were summarized using frequencies and percentages.

Because MMS achievement showed a markedly right-skewed distribution (skewness = 3.30), non-parametric statistical

methods were used for inferential analyses. Differences in MMS achievement across regions and reporting periods were assessed using the Kruskal-Wallis test, followed by Benjamini-Hochberg-adjusted pairwise Wilcoxon tests when appropriate. Regional and temporal effect sizes were quantified using epsilon-squared (ε^2).

Differences between Existing and Expansion woredas were assessed using the Wilcoxon rank-sum test, and effect sizes were estimated using the rank-biserial correlation coefficient. Additional analyses compared achievement between 2025 and 2026 separately within Existing and Expansion woredas.

Missing MMS achievement data were summarized overall and stratified by year, region, and implementation status. Primary analyses used available-case observations. Because completeness declined substantially during 2026, temporal comparisons involving this period were interpreted cautiously.

Sensitivity Analyses

Sensitivity analyses evaluated the influence of extreme achievement values, patterns of missing outcome data, and clustering of repeated observations within woredas. A mixed-effects model including calendar year and implementation status as fixed effects and woreda as a random intercept was fitted as a sensitivity analysis to assess consistency with the primary non-parametric findings. Full model outputs are presented in Appendix 1.

A two-sided p-value <0.05 was considered statistically significant. All analyses were conducted using R statistical software (R Foundation for Statistical Computing, Vienna, Austria).

Data Management and Quality Assurance

Data were reviewed for completeness, consistency, duplication, and formatting errors prior to analysis. Outcome and implementation indicators were screened for missing values and implausible entries using descriptive summaries and graphical assessment. Several implausible stockout values were identified as spreadsheet-formatting artifacts and were excluded from interpretation. Data cleaning procedures and analytical decisions were documented to ensure transparency and reproducibility.

Reporting Guidelines

This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Results

Dataset Characteristics and Data Completeness

The final analytical dataset comprised 2,268 unique woreda-month observations, of which 1,724 (76.0%) had sufficient information to calculate MMS achievement (Table 1).

Table 1. MMS Achievement Data Completeness among Monthly Reporting Observations, by Reporting Period, Ethiopia, January 2023-June 2026

Reporting period	Total observations	Achievement available, n (%)	Achievement missing, n (%)
2023	252	248 (98.4)	4 (1.6)
2024	252	250 (99.2)	2 (0.8)
2025	866	811 (93.6)	55 (6.4)
2026 (Jan–Jun)	898	415 (46.2)	483 (53.8)
Total	2,268	1,724 (76.0)	544 (24.0)

Note: *MMS achievement could not be calculated where target or achievement values were missing.*

Distribution of MMS Achievement

Among the 1,724 observations with available achievement data, mean MMS achievement was 100.2% (SD = 56.3), while median achievement was 94.6% (IQR: 70.5%–120.4%). Achievement ranged from 0% to 729%, indicating substantial variability in implementation performance. Overall, 752 (43.6%) observations achieved at least 100% of the monthly target. The distribution of MMS achievement categories among observations with available achievement data is presented in Table 2.

Table 2. Distribution of MMS Achievement among Observations with Available Achievement Data, Ethiopia, January 2023–June 2026

Achievement level	n	%
<50%	220	12.8
50–<80%	372	21.6
80–<100%	380	22.0
100–<120%	316	18.3
≥120%	436	25.3
Total	**1,724**	**100.0**

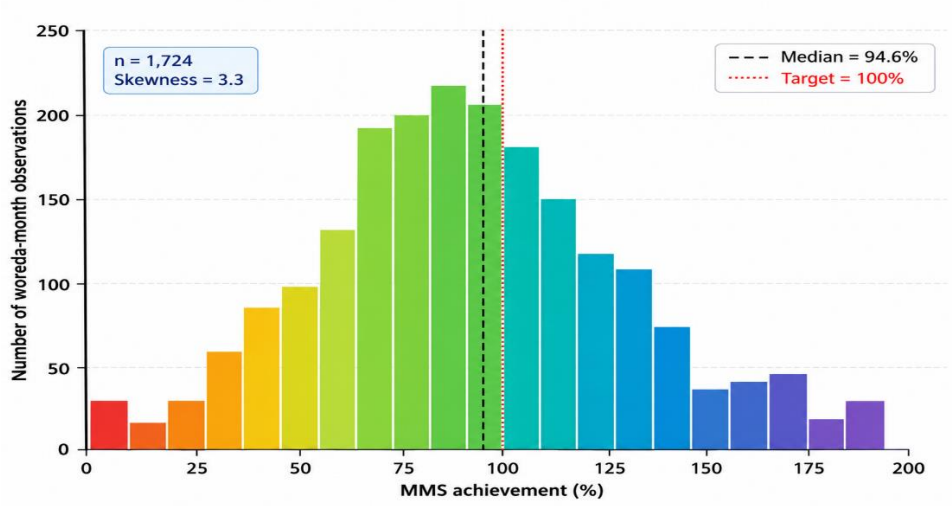


Figure 2. Distribution of MMS Achievement among Reporting Observations, Ethiopia, January 2023–June 2026

Note: *The dashed black line indicates the median achievement (94.6%), while the dotted red line indicates the program target (100%). The histogram was truncated at 200% for visualization purposes; all observations were retained in the analysis.*

The distribution of MMS achievement was positively skewed, with a small number of observations reporting exceptionally high achievement values (Figure 2). The lower median relative to the mean indicates that overall achievement was influenced by a relatively small number of high-performing observations.

Temporal Trends in MMS Achievement

MMS achievement varied across reporting periods (Table 3, Figure 3). Median achievement remained stable at 98.8% during 2023 and 2024, before declining to 93.2% in 2025 and 89.9% during January-June 2026. Mean achievement exceeded the median in all reporting periods, consistent with the right-skewed distribution of achievement values.

Table 3. MMS Achievement by Reporting Period, Ethiopia, January 2023–June 2026

Reporting period	Total observations, N	Achievement available, n	Missing, n (%)	Median (IQR), %	Mean, %
2023	252	248	4 (1.6)	98.8 (80.0–122.0)	103.0
2024	252	250	2 (0.8)	98.8 (77.0–130.0)	107.0
2025	866	811	55 (6.4)	93.2 (66.4–121.0)	98.4
2026 (Jan–Jun)	898	415	483 (53.8)	89.9 (68.6–112.0)	98.0

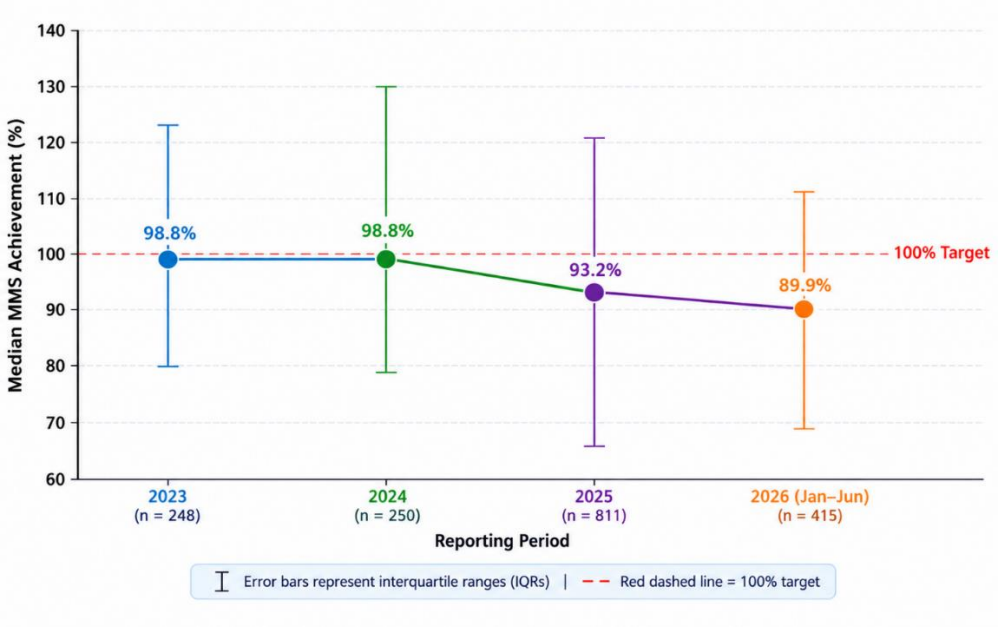


Figure 3. Median MMS Achievement by Reporting Period, Ethiopia, January 2023–June 2026

Median achievement was lower during 2025 and January-June 2026 than during 2023-2024; however, the overall reporting-period effect was small ($\varepsilon^2 = 0.0077$), and interpretation of 2026 estimates is constrained by substantial missing outcome data.

Achievement of Monthly Targets

Overall, 752 of 1,724 observations (43.6%) achieved at least 100% of the monthly MMS target (Table 4). Achievement rates varied modestly across reporting periods, ranging from 41.8% to 49.2%.

Table 4. Achievement of Monthly MMS Targets among Observations with Available MMS Achievement Data, Ethiopia, January 2023–June 2026

Reporting period	Available observations	Achieved ≥100%, n	Achievement rate (%)
2023	248	116	46.8
2024	250	123	49.2
2025	811	339	41.8
2026 (Jan–Jun)	415	174	41.9
Total	**1,724**	**752**	**43.6**

These findings indicate that fewer than half of reporting observations achieved their monthly MMS targets, despite overall mean achievement remaining close to 100%.

MMS Achievement by Woreda Implementation Status

MMS achievement differed between Existing and Expansion woredas (Table 5). Among observations with available outcome data, median achievement was higher in Existing woredas (96.4%) than in Expansion woredas (85.3%). Achievement data were also more complete in Existing than Expansion woredas (79.4% vs. 69.0%).

Table 5. MMS Achievement and Data Completeness by Woreda Implementation Status, Ethiopia, January 2023–June 2026

Measure	Existing	Expansion
Total observations	1,533	735
Achievement available, n (%)	1,217 (79.4)	507 (69.0)
Missing achievement, n (%)	316 (20.6)	228 (31.0)
Mean achievement (%)	101.0	98.6
SD	44.4	77.9
Median achievement (%)	96.4	85.3
25th percentile (%)	75.9	55.6
75th percentile (%)	120.0	121.0

The Wilcoxon rank-sum test indicated a statistically significant difference in MMS achievement between Existing and Expansion woredas ($W = 345{,}917$, $p < 0.001$). However, the magnitude of the difference was small (rank-biserial correlation = 0.126).

Geographic Variation in MMS Achievement

MMS achievement varied significantly across regions (Kruskal-Wallis $\chi^2(12) = 99.01$, $p < 0.001$), indicating geographic heterogeneity in implementation performance. Although statistically significant, the magnitude of regional differences was modest ($\varepsilon^2 = 0.051$). Pairwise comparisons with Benjamini-Hochberg adjustment identified significant differences between multiple regional pairs. Detailed regional summaries of MMS achievement and reporting completeness are presented in Table 6.

Table 6. Regional Variation in MMS Achievement among Monthly Reporting Observations, Ethiopia, January 2023-June 2026

Region	Total observations, n	Achievement available, n (%)	Mean (%)	Median, %
Oromia	689	565 (82.0)	108.0	102.0
Dire Dawa	184	120 (65.2)	105.0	102.0
SNNP	288	248 (86.1)	107.0	100.0
Addis Ababa	69	50 (72.5)	95.5	98.2
Gambela	48	39 (81.3)	96.8	96.8
SER	22	12 (54.5)	102.0	90.7
Sidama	96	84 (87.5)	89.4	88.7
Amhara	189	138 (73.0)	88.8	86.7
Benishangul-Gumuz	24	9 (37.5)	84.3	82.1
Harari	207	131 (63.3)	83.9	81.1
Afar	48	33 (68.8)	84.4	79.4

Tigray	216	147 (68.1)	118.0	77.3
Somali	188	148 (78.7)	78.1	64.1
Total	2,268	1,724 (76.0)	—	—

Note: *Regional estimates should be interpreted cautiously for regions with small numbers of observations, particularly SER (n = 22) and Benishangul-Gumuz (n = 24).*

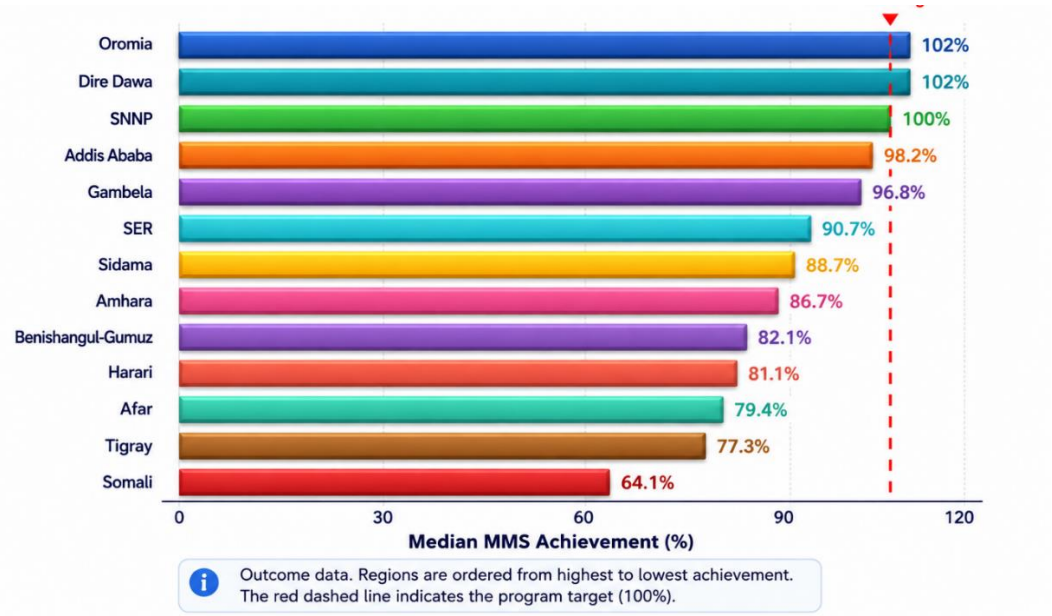


Figure 4. Regional Variation in Median MMS Achievement among Reporting Observations, Ethiopia, January 2023-June 2026

Note: *Values represent median MMS achievement among observations with available achievement data.*

Median MMS achievement ranged from 64.1% in Somali Region to 102.0% in Oromia and Dire Dawa (Figure 4). Tigray reported the highest mean achievement (118.0%) but a substantially lower median achievement (77.3%), suggesting a strongly right-skewed distribution influenced by a small number of high-achievement observations.

Data Quality and Reporting Completeness

Data completeness varied substantially across MMS monitoring indicators. MMS achievement data were missing for 544 (24.0%) of the 2,268 woreda-month observations. Missingness was higher for several supporting implementation indicators, including community dialogue information (800 observations), awareness-creation information (797 observations), and health-worker training information (876 observations).

Information on three-month supply availability was reported as available in 1,185 (52.2%) observations and unavailable in 192 (8.5%), while 891 (39.3%) observations had missing supply information.

Data-quality concerns were also identified for the stockout indicator. Several records contained implausible values corresponding to spreadsheet date serial numbers rather than valid stockout counts. These observations were interpreted as probable data-entry or formatting errors and were excluded from interpretation. The pattern of MMS achievement data completeness across reporting periods is illustrated in Figure 5.

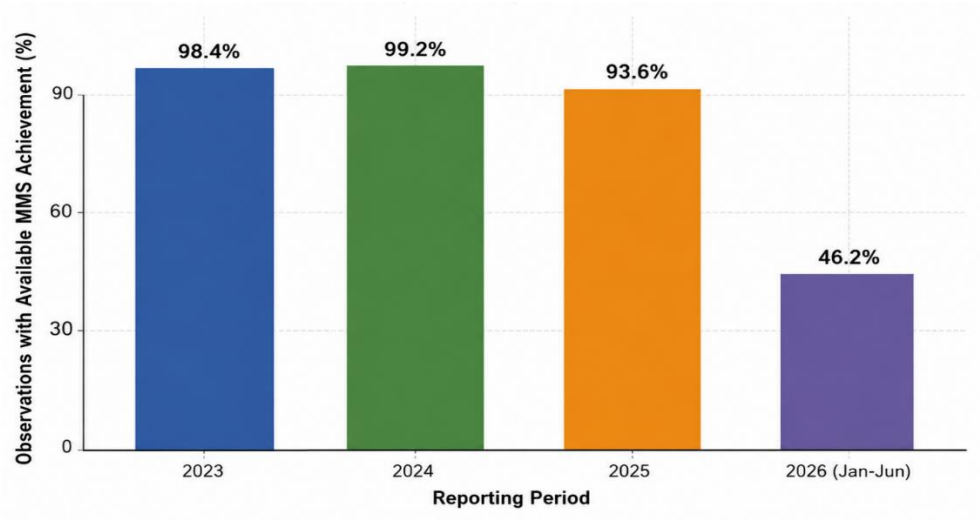


Figure 5. Completeness of MMS achievement data by reporting period, Ethiopia, January 2023–June 2026

Note: *Completeness was calculated as the proportion of observations with sufficient information to estimate MMS achievement. Reporting completeness declined substantially during January–June 2026.*

Completeness remained above 93% during 2023-2025 but declined sharply to 46.2% during January-June 2026. Missingness exceeded 50% in both Existing and Expansion woredas, indicating that reporting challenges were widespread rather than confined to newly implementing areas.

Sensitivity Analyses

Sensitivity analyses were conducted to assess the robustness of the primary findings. Excluding observations with MMS achievement values exceeding 300% did not materially alter the distribution of achievement or the principal conclusions (Appendix 2). Similarly, missing outcome data during January-June 2026 were comparable between Existing and Expansion woredas (53.6% and 54.1%, respectively). A mixed-effects sensitivity analysis accounting for repeated observations within woredas produced findings consistent with the primary non-parametric analyses (Appendix 1). A summary of the principal inferential analyses is presented in Table 7.

Table 7. Summary of Inferential Analyses of MMS Achievement, Ethiopia, January 2023-June 2026

Comparison	Statistical test	Test statistic	P-value	Effect size
Region (13 regions)	Kruskal–Wallis	$\chi^2 = 99.008$ (df = 12)	<0.001	$\varepsilon^2 = 0.051$
Reporting period (2023–2026)	Kruskal–Wallis	$\chi^2 = 16.315$ (df = 3)	0.001	$\varepsilon^2 = 0.0077$
Existing vs Expansion	Wilcoxon rank-sum	W = 345,917	<0.001	rrb = 0.126
Existing: 2025 vs 2026 (Jan–Jun)	Wilcoxon rank-sum	W = 57,499	0.970	—
Expansion: 2025 vs 2026 (Jan–Jun)	Wilcoxon rank-sum	W = 30,207	0.430	—

Regional differences in MMS achievement were statistically significant but modest in magnitude ($\varepsilon^2 = 0.051$), whereas temporal differences across reporting periods were statistically significant but very small ($\varepsilon^2 = 0.0077$). Existing woredas achieved significantly higher MMS performance than Expansion woredas, although the effect size was small (rrb = 0.126). No statistically significant differences were observed between 2025 and January-June 2026 within either implementation-status group.

Discussion

Principal Findings

This study assessed temporal and geographic variation in MMS implementation performance during national scale-up in Ethiopia using routine monitoring data collected between January 2023 and June 2026. Overall, MMS achievement remained close to program targets when summarized by the mean, although the median achievement was lower, indicating substantial variability across reporting observations. Performance differed significantly across regions and implementation settings, with Existing woredas generally achieving higher performance than Expansion woredas. A notable finding was the sharp decline in reporting completeness during January-June 2026, which limits confidence in the interpretation of recent temporal trends.

These findings suggest that MMS implementation performance was generally maintained during scale-up but was characterized by substantial heterogeneity across regions and implementation contexts. Although achievement appeared lower during the most recent reporting period, the combination of small temporal effect sizes and substantial missing outcome data suggests caution in interpreting this pattern as evidence of a meaningful decline in national performance.

Geographic and Implementation Variation

The significant geographic variation observed in this study is consistent with implementation research demonstrating that maternal nutrition interventions often perform differently across health-system and geographic contexts. Differences in service accessibility, workforce capacity, supervision, supply-chain performance, leadership, community engagement, and reporting systems may all contribute to variation in implementation performance [5, 10, 14].

Although regional differences were statistically significant, their overall magnitude was modest, suggesting that region alone explains only a limited proportion of the observed variation. Considerable heterogeneity is likely to exist within regions at woreda and facility levels. Consequently, identifying the operational characteristics associated with high-performing implementation areas may offer greater value for program improvement than focusing solely on regional averages.

Existing woredas achieved higher MMS performance than Expansion woredas; however, the observed effect size was small. This finding is consistent with implementation research showing that newly adopted service-delivery areas often require time to establish reporting systems, provider capacity, supervision mechanisms, and routine operational processes [20, 21]. At the same time, the modest magnitude of the difference suggests that implementation status alone does not account for most of the variability in MMS achievement.

Future studies incorporating facility-level and qualitative data may help explain the operational factors underlying observed geographic differences in MMS implementation performance.

Temporal Trends in MMS Achievement

MMS achievement differed significantly across reporting periods, but the magnitude of the difference was very small ($\varepsilon^2 = 0.0077$). Median achievement remained stable during 2023 and 2024, followed by lower median achievement in 2025 and January–June 2026. The apparent decline therefore coincided temporally with the transition from pilot implementation toward broader national scale-up.

However, the interpretation of this temporal pattern requires caution. The 2026 estimate represents January–June only, rather than a complete calendar year, and achievement data were available for less than half of reporting

observations during this period. Furthermore, within-status comparisons found no statistically significant difference between 2025 and January–June 2026 among either Existing or Expansion woredas.

Taken together, these findings suggest that there is evidence of variation across reporting periods but limited evidence that MMS achievement changed substantially between the two most recent periods within implementation-status groups. The observed decline in the overall 2026 median may therefore reflect a combination of true implementation variation and changes in the composition and completeness of reporting.

This distinction is particularly important for routine program monitoring. Apparent changes in performance should be interpreted alongside changes in reporting completeness and the geographic composition of reporting observations rather than considered in isolation.

Data Quality and Reporting Completeness

Data quality and reporting completeness emerged as some of the most important findings of this study. While MMS achievement data were highly complete during 2023-2025, completeness declined substantially during January-June 2026. Similar challenges were observed across other implementation indicators, including training, community engagement, and supply-monitoring variables.

The timing of this decline coincided with rapid program expansion. Although causality cannot be established from the available data, expansion may have increased demands on reporting systems, supervision structures, and data-management processes. Similar challenges have been reported in routine health information systems during periods of rapid scale-up and system transition [21].

Several stockout records also contained implausible values consistent with spreadsheet-formatting errors, illustrating the vulnerability of manually managed monitoring systems to data-entry and validation challenges. These findings highlight the importance of viewing data quality as an integral component of implementation performance rather than a separate monitoring activity.

Because more than half of observations lacked achievement data during January-June 2026, estimates from this period should be interpreted as reflecting reporting observations rather than definitive national performance. The similar level of lack missingness among Existing and Expansion woredas suggests that reporting challenges were widespread rather than confined to newly implementing areas.

Implications for National MMS Scale-Up

The findings have several implications for ongoing national MMS implementation. First, implementation support should be targeted toward lower-performing regions and implementation areas identified through routine monitoring. Geographic performance differences suggest that some areas may benefit from additional supervision, mentoring, and operational support.

Second, newly implemented areas may require intensified support during the transition to routine MMS delivery. Structured supervision, commodity-management support, provider training, and routine performance reviews may help strengthen implementation during early phases of expansion.

Third, data quality should be treated as a core implementation outcome. The marked decline in reporting completeness demonstrates that rapid geographic expansion without corresponding investment in monitoring capacity can reduce the usefulness of routine program data for decision-making.

Finally, integration of MMS indicators into national digital health information systems may improve sustainability, standardization, data validation, and reporting completeness. Such investments would strengthen both

implementation monitoring and accountability during future scale-up efforts.

Strengths

This study has several strengths. It utilized routine MMS monitoring data collected during the transition from pilot implementation to national scale-up, providing insight into implementation performance under real-world program conditions. The analysis included 2,268 unique woreda-month observations across 13 regions, offering substantial temporal and geographic coverage. The use of non-parametric statistical methods, effect-size estimation, and sensitivity analyses strengthened the robustness of findings. In addition, the study examined both implementation performance and reporting completeness, providing a broader assessment of program functioning during national expansion.

Limitations

Several limitations should be considered. First, the study relied on routine program monitoring data that were not collected primarily for research purposes and may therefore be affected by reporting inconsistencies, data-entry errors, and variation in indicator quality. Second, MMS achievement data were missing for 24.0% of observations overall and for more than half of observations during January-June 2026, potentially introducing bias if missingness was related to implementation performance. Third, the 2026 data represent only the first six months of the year, limiting direct comparison with previous reporting periods. Fourth, a small number of extreme achievement values were observed, although sensitivity analyses indicated that these observations did not materially influence the main findings. Finally, the observational design does not permit causal inference, and substantial missingness in several implementation indicators limited exploration of factors underlying geographic and temporal variation in MMS achievement.

Conclusion

MMS implementation performance in Ethiopia remained broadly aligned with program targets during national scale-up, but substantial variation was observed across regions and implementation settings. Existing implementation areas generally achieved higher performance than newly expanded woredas, while geographic differences highlighted the importance of local implementation context. Although achievement appeared lower during the most recent reporting period, interpretation of this pattern is constrained by the marked deterioration in reporting completeness.

As Ethiopia continues national MMS expansion, strengthening implementation support, routine monitoring systems, data quality assurance, and reporting completeness will be essential to ensure equitable and sustainable program delivery. Particular attention should be given to lower-performing areas and newly implementing woredas to support consistent implementation and maximize the potential population-health benefits of MMS.

Conflict of Interest

The author declares no conflict of interest regarding the publication of this study.

Acknowledgements

The author acknowledges the Ministry of Health, the Ethiopian Public Health Institute (EPHI), and partners supporting the national MMS program for facilitating access to routine monitoring data (UNICEF). Appreciation is also extended to academic supervisors and colleagues who provided technical guidance during the study.

Author Contributions

Abnet Tesfaye Kebede conceived the study, conducted the data analysis, interpreted the findings, and prepared the manuscript.

Ethics Approval

This study utilized secondary analysis of routinely collected, aggregated MMS program monitoring data and did not involve direct contact with human participants. The dataset contained no personal identifiers and was analyzed solely for research purposes.

Data Availability

The data used in this study are derived from the national MMS routine monitoring system and are not publicly available. Access may be granted by the relevant program authorities subject to applicable permissions and data-sharing requirements.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art014

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Timeliness and Completion of Routine Childhood Vaccination and Associated Factors among Children Aged 0–59 Months in Tiko Health District, Southwest Region, Cameroon

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Cite this article as: Ngo Billong Christiane Peggy, Ojong-Ebot Ayukndip, Talongwa Roberto, Adiogo Dieudonnee. Timeliness and Completion of Routine Childhood Vaccination and Associated Factors among Children Aged 0–59 Months in Tiko Health District, Southwest Region, Cameroon. Texila Int J Acad Res. 2026;13(4).
https://doi.org/10.21522/TIJAR.2014.13.04.Art014

Received: 28.08.2026

Accepted: 23.09.2026

Published: 30.10.2026

Article Type: Original Research

Abstract *Childhood vaccination remains a major public health challenge; global third-dose coverage of the combined diphtheria, tetanus, and pertussis (DTP3) vaccine reached 85% in 2025, yet 13.5 million children remained zero-dose. In Cameroon, national third-dose coverage of the combined diphtheria, tetanus and pertussis vaccine (DTP3) rose to 82.5% in 2024, but sub-national performance remains undocumented: a South-West Region study reported only 47.7% coverage. Whether the Tiko Health District follows this national pattern of declining coverage between initial and subsequent doses had not previously been documented. This cross-sectional study assessed vaccination coverage, timeliness, and associated factors in the Tiko Health District, combining a review of 800 vaccination records and a survey of 604 caregivers of children aged 0–59 months. Age-appropriate vaccination completion was 30.3% (242/800). Coverage declined markedly from 98.6% for Bacillus Calmette-Guerin (BCG) and 76.0% for Pentavalent 1 (Penta1) to 48.1% for Pentavalent 3 (Penta3) and 9.0% for the first measles-rubella (MR) dose. Timeliness remained high for later doses (95.3% for Penta3) despite low coverage. Untimely vaccination was significantly associated with caregivers' lack of schedule knowledge adjusted odds ratio [aOR] = 4.3; 95% confidence interval [CI]: 2.41–7.92), absence of reminders (aOR = 2.2; 95% CI: 1.30–3.66), and age of child under 5 years in the household (aOR = 3.22; 95% CI: 1.26–8.26). Routine immunisation in Tiko shows high initial access but substantial attrition across subsequent doses, indicating that retention, rather than initial uptake, is Tiko's principal challenge. Caregiver knowledge and reminders emerged as the strongest modifiable determinants of timeliness, pointing to clear priorities for improving retention and equity in the district.*

Keywords *Childhood Vaccination, Cameroon, Immunization Services, Vaccination Timeliness, Vaccination Completion, Vaccination Coverage.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art014

Introduction

Vaccination remains one of the most effective public health interventions for reducing childhood morbidity and mortality from vaccine-preventable diseases. However, the performance of an immunisation programme depends not only on the proportion of children who receive recommended vaccines, but also on the timeliness of vaccine administration and the completion of the vaccination schedule. Delayed vaccination prolongs the period during which a child remains insufficiently protected, while dropout between successive doses compromises the development of optimal immunity. These shortcomings may sustain pockets of susceptibility and facilitate the transmission of vaccine-preventable diseases, even when overall administrative coverage appears satisfactory.

In Cameroon, despite recent progress, gaps in routine immunisation remain. According to the United Nations Children's Fund (UNICEF), national coverage with the third dose of the diphtheria, tetanus, and pertussis vaccine (DTP3), a key indicator of routine immunisation programme performance, increased from 79.2% in 2022 to 82.5% in 2023 and remained at 82.5% in 2024, still below programme targets [1]. This marks a sustained improvement compared with the 2018 Cameroon Demographic and Health Survey, in which full basic vaccination coverage among children aged 12–23 months was substantially lower [7], though the persistence of a gap below programme targets indicates that progress has not yet translated into full closure of the coverage gap. Globally, DTP3 coverage was estimated at 85% in 2024, while coverage for the first measles-containing vaccine dose (MCV1) reached 84% [2]. The most recent World Health Organization (WHO)/UNICEF Estimates of National Immunization Coverage (WUENIC) confirm this plateau at the global level [11, 12], underscoring that the retention challenge documented in this study reflects a pattern observed well beyond Cameroon. These figures indicate that achieving high and equitable vaccine coverage remains challenging, particularly in settings where children discontinue vaccination after the initial doses.

Sub-national evidence from the South-West Region further suggests that district-level performance can fall well below these national figures: a household survey conducted in the Mbonge Health Area found that only 47.7% of children aged 9–23 months were fully vaccinated according to cards and caregiver recall [22], underscoring the need for district-specific data such as those generated by the present study.

Beyond vaccination coverage, several studies have emphasised the importance of assessing the actual age at vaccine administration. An analysis of 70,006 children across 33 Sub-Saharan African countries, using data from 2020, revealed that 25.9% of children received BCG at least one month late, 49.1% received the third dose of the pentavalent vaccine (Penta3) late, and 63.9% received the first measles vaccine dose late. Vaccination delays were also significantly associated with incomplete vaccination schedules by 12 months of age. Specifically, delayed Penta3 vaccination was associated with a 50% increase in the odds of schedule non-completion (aOR = 1.50; 95% CI: 1.35–1.64) [3]. These findings suggest that vaccination coverage measured independently of administration timing may conceal substantial periods of vulnerability among children.

This issue has also been documented in Cameroon. In the Dschang Health District, Zeufack et al. (2023) assessed vaccination timeliness among children aged 0 to 23 months. Among children with documented vaccination dates, the proportion vaccinated within the recommended timeframes ranged from approximately 42% to 76% depending on the antigen, while the prevalence of missed opportunities for vaccination was estimated at

23.8%. Furthermore, approximately 18% of children with usable vaccination records were not fully vaccinated [4].

These findings highlight the substantial gap between vaccine receipt and vaccination according to recommended schedules. Deficiencies in vaccination timeliness and completion may result from interactions between child- and caregiver-related factors, including knowledge of the vaccination schedule and socioeconomic characteristics, as well as health system factors such as session organisation, missed opportunities, vaccine availability, geographical accessibility, and service quality. These challenges may be particularly pronounced in settings affected by humanitarian or security crises. In 2024, UNICEF estimated that 3.4 million people, including 1.9 million children, required humanitarian assistance in Cameroon due to armed conflicts, population displacement, epidemics, and other crises that may disrupt access to essential health services, including immunisation [5].

The Tiko Health District, located in Cameroon's South-West Region, operates within this context and may face socioeconomic, organisational, and service access constraints that affect continuity of childhood immunisation. However, data simultaneously assessing vaccination coverage, timeliness of vaccine administration, schedule completion, and factors associated with these performance indicators remain limited in this district. This study therefore aims to evaluate the performance of immunisation services in the Tiko Health District, with particular emphasis on vaccination timeliness and schedule completion.

Methods and Materials

Study Design and Setting

A cross-sectional quantitative study was conducted in the Tiko Health District of the South-West Region of Cameroon, to assess the timeliness and completion of routine childhood immunisation and to identify associated socio-demographic, caregiver-related, and health-system factors.

Sample Size Determination

The study used two complementary data sources: a household-based survey and a retrospective review of childhood vaccination records from selected health facilities. A formal statistical sample size calculation was not performed. Instead, a pragmatic, non-probability sampling approach was used, taking into consideration the availability and accessibility of eligible study participants and vaccination records during the study period, as well as the time and logistical resources available for data collection.

For the household survey, eligible caregivers of children aged 0–59 months were recruited from the selected communities during the study period. A total of 604 eligible caregivers were included in the household survey. Caregivers were eligible if they were responsible for the care of an eligible child and provided the required information for the assessment of the child’s vaccination status and factors potentially associated with vaccination timeliness. Of the 604 caregivers interviewed, 603 had complete information on vaccination timeliness and were therefore included in the bivariate and multivariate analyses. One record was excluded from the regression analysis because the outcome variable for timeliness was missing. Thus, the analytical sample for factors associated with untimely vaccination was 603 participants, as reported in Table 5.

For the facility-based record review, five health facilities were purposively selected to provide representation of the different facility settings and types included in the study. The sampling frame comprised vaccination records for children aged 0–59 months available in the selected facilities during the period from 04 June to 1er July 2026, Records were eligible for inclusion if they belonged to children aged 0–59 months and contain sufficient

vaccination information to determine vaccination status and/or timeliness. Records that were illegible or lacked sufficient identifying information were excluded.

A total of approximately 800 eligible vaccination records were reviewed across five health facilities. All eligible records available during the record review period were included. Table 1 shows the number of records reviewed from each facility. The facility records were used to estimate antigen-specific vaccination coverage, age-appropriate vaccination completion, and vaccination timeliness.

The two datasets served complementary purposes: household-level data were used to examine caregiver, socioeconomic, and health-system factors associated with untimely vaccination, while facility-based records were used to describe vaccination coverage, completion and timeliness.

Sampling Technique

This study employed two sampling approaches for the two different data sets.

For the household survey, a multistage sampling technique was used to select households. The sampling process involved the sequential selection of health areas, communities, and households.

- **Stage 1 — Selection of health areas:** The sampling frame consisted of the health areas of the Tiko Health District. Health areas were randomly selected using balloting.
- **Stage 2 — Selection of communities:** Within the selected health areas, communities were selected from the sampling frame obtained from the district health service, using simple random sampling.
- **Stage 3 — Selection of households:** Households in the selected communities were identified using the community register provided by the Community Health Workers (CHWs). The required number of households was selected using systematic random sampling, with the sampling interval calculated by dividing the total number of eligible households by the required number of households.

For this study, a household was defined as a group of people living under the same roof and feeding in the same pot. Households were eligible if there was a child aged 0–59 months. If a selected household was ineligible, vacant, could not be located after the revisit, or declined participation, it was replaced using the next household according to the predetermined sampling procedure.

For the health facility record review, purposive sampling was used. Facilities were selected to ensure representation according to geographical setting, facility type, and volume of immunisation services, while ensuring that adequate vaccination records were available for review (Table 1).

Table 1. Selection of Health Facilities

S/N	Health facility	Health area	Setting	Facility type	Basis for selection	Number of records reviewed
1	CMA Mutengene	Mutengene	Urban	Public	Facility used regularly	152
2	Mbingo,mutengune	Likomba	Urban	Confessional	Reception/Staff attitude	154
3	IHC Holforth	Holforth	Urban	Public	Facility used regularly	307
4	HC Tiko Town	Tiko Town	Rural	Public	Crowding	165
5	HC Misellele	Misellele	Rural	Public	Distance	22

Facilities were selected to jointly represent three operational characteristics observed to influence immunisation service performance during the scoping phase, routine service utilisation volume ("facility used regularly"), staff, caregiver interaction quality ("reception/staff attitude"), and physical access constraints ("crowding", "distance"),so that the reviewed records and surveyed caregivers reflect the range of conditions encountered across the district rather than a single facility profile.

Data Collection Methods

Data for this study were collected at two levels. First, data were collected from existing records in selected health facilities. Trained research assistants systematically reviewed vaccination registers and child health records for children aged 0–59 months, extracting information on date of birth, sex, dates of administration of all routine vaccines, and health facility code. Maternal identification information was used only for cross-checking when necessary, while maintaining confidentiality. This approach enabled an objective assessment of vaccination timeliness and completion based on official records.

Second, for the household survey (individual interviews), structured questionnaires were administered to primary caregivers of children aged 0–59 months in selected households through face-to-face interviews conducted by trained research assistants. Data were collected on socio-demographic characteristics, children's vaccination status, caregiver-reported reasons for delayed or missed vaccination, knowledge and attitudes toward immunisation, access to health information and services, perceived quality of vaccination services, distance and transportation barriers, and vaccination card retention. Caregivers were asked to present the child's vaccination card for verification; when unavailable, caregiver recall was cautiously used and documented during data collection.

Questionnaire for Risk Factors and Demographic Data

A structured questionnaire was used to collect socio-demographic, socioeconomic, caregiver-related, and health-system data potentially associated with incomplete and untimely routine childhood vaccination. Information collected included child and caregiver characteristics, caregiver education and occupation, household characteristics, knowledge of the routine immunisation schedule, vaccination reminders, access to health information and immunisation services, distance and transportation barriers, waiting conditions, and perceived quality of vaccination services. Vaccination status was verified using the child's vaccination card when available. These data enabled the assessment of factors associated with incomplete and untimely routine vaccination among children aged 0–59 months in the Tiko Health District.

Data Variables

Age-appropriate vaccination completion and timely vaccination were the primary outcome variables. Age-appropriate vaccination completion was defined as receipt of all vaccine doses due according to the child's age at the time of assessment, based on the national routine immunisation schedule applicable during the study period. For each child, we determined age at assessment, identified the vaccines and doses due by that age, and compared documented vaccination history with the expected schedule. Children who had received all doses due for their age were classified as complete for age (coded 1), while those who had missed one or more doses due by their age were classified as incomplete for age (coded 0).

Timely vaccination was defined as receipt of each vaccine dose within the recommended age or interval specified in the national routine immunisation schedule applicable during the study period. Operationally, we defined timely as receipt of the vaccine dose at the

recommended age or within four weeks after the recommended age, provided the minimum interval between doses was respected. The recommended schedule consisted of BCG and OPV-0 at birth; DTP-HepB-Hib 1, PCV-13 1, OPV-1 and Rotavirus 1 at 6 weeks; DTP-HepB-Hib 2, PCV-13 2, OPV-2 and Rotavirus 2 at 10 weeks; DTP-HepB-Hib 3, PCV-13 3 and OPV-3 at 14 weeks; MR1 and Yellow Fever vaccines at 9 months, and MR2 at 15 months.

For each child, the recorded date of administration of each vaccine dose was compared with the scheduled age or minimum interval for that dose. A vaccine dose was classified as timely (coded 1) if it was administered within the predefined acceptable time window around the recommended date/age the exact allowable window for each dose is specified in Table 2 and as untimely (coded 0) if it was administered outside this window. The acceptable time window was defined based on the Cameroon national immunisation schedule and applied consistently across vaccine doses. For accines administered as a series, timeliness of subsequent doses was assessed using the recommended minimum interval from the preceding dose. Children whose relevant vaccination date was not documented were classified as having missing timeliness data rather than being assumed to have received the vaccine late. At the child level, timely vaccination was determined by assessing whether all vaccine doses due and documented for the child's age had been received within their respective recommended time windows. The analysis also assessed timeliness separately for individual vaccine doses to identify points in the immunisation schedule at which delays were most frequent.

Table 2. Vaccine Operational Definition

Vaccine Dose	Recommended Age	Timely if administered
BCG	At birth	On the day of birth or within 28 days after birth
Penta 1	6 weeks	At 6 weeks through 10 weeks of age
Penta 2	10 weeks	At 10 weeks through 14 weeks of age and at least 4 weeks after Penta 1
Penta 3	14 weeks	At 14 weeks through 18 weeks of age and at least 4 weeks after Penta 2
MR 1	9 months	At 9 months through 10 months of age
MR 2	15 months	At 15 months through 16 months of age and at least 6 months after MR 1

Explanatory variables included child and caregiver socio-demographic characteristics, socioeconomic factors, caregiver knowledge of the routine immunisation schedule, receipt of vaccination reminders, number of children under five years in the household, distance to vaccination services, transportation barriers, waiting conditions, and perceived quality of immunisation services.

Data Analysis

Quantitative data were analysed using SPSS version 25. Descriptive statistics were used to summarize participants' characteristics and vaccination outcomes. Categorical variables were presented as frequencies and percentages, while continuous variables were summarized using means and standard deviations or medians and interquartile ranges, as appropriate. Vaccination coverage, age-appropriate vaccination completion, and timeliness were estimated as proportions.

Age-appropriate vaccination completion was defined as a binary outcome variable (complete for age = 1; incomplete for age = 0)

by comparing each child's documented vaccination history with the doses expected for their age under the applicable national immunisation schedule. Bivariate logistic regression was performed to assess associations between explanatory variables and untimely vaccination, and crude odds ratios (cORs) with 95% confidence intervals (CIs) were reported. Variables considered for the multivariable model were entered into a multivariable logistic regression analysis to identify factors independently associated with untimely vaccination. Variable selection was based on a combination of epidemiological relevance, and findings from the bivariate analysis. Variables considered important a priori based on their potential relationship with vaccination timeliness, including child, caregiver, household, socioeconomic, and health system characteristics, were considered for inclusion. In addition, variables with a p-value <0.20 in the bivariate analysis were considered candidates for the multivariate model. We reported adjusted odds ratios (aORs) with 95% CIs and set statistical significance at $p < 0.05$.

Ethical Consideration

Ethical clearance was obtained from the Regional Ethics Committee for Human Health Research of the Southwest Region of Cameroon (04/CRERSH/SW/C/02/2026). Authorisations were sought from the Southwest Regional Delegation of Public Health (P42/MINSANTE/SWR/RDPH/RCB.PT/04/2026), the Regional Expanded Programme on Immunization (EPI) Officer Southwest (P12/MINSANTE/SWR/RDPH/EPI/), and Tiko Health District (N°2026/28vol/MINSANTE/RDPHSW/THD/504). All procedures involving human participants were conducted in accordance with the ethical standards of the institutional and national research committees and in compliance with the principles of the Declaration of Helsinki [13]. Written informed consent to participate was obtained from all study participants before data collection. The study was conducted in accordance with the International Council for Harmonisation Good Clinical Practice (ICH-GCP) guidelines [15] and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [14].

Results

Socio-demographic and Health-Facility Characteristics of Children Included in the Record Review

For the record review, a total of 800 children were included, comprising 660 (82.5%) aged 0–11 months and 140 (17.5%) aged 12–59 months. The ages of children reviewed ranged from 0 to 59 months, with a mean age of 6.3 months (standard deviation [SD] = 3.8). The median age was 6 months, with an interquartile range (IQR) of 3 to 9 months. Regarding sex, 407 (50.9%) of the children were female and 393 (49.1%) were male.

More than half of the children (458, 57.3%) attended confessional health facilities, followed by public facilities (324, 40.5%), while only 18 (2.3%) attended private facilities. Among the five health areas, Mutengene Health Area accounted for the largest proportion of participants, 424 (53.0%), followed by Likomba, 182 (22.8%). More than half of the children, 459 (57.4%), resided in urban areas (Table 2).

Table 3. Socio-demographic Characteristics of the Vaccination Records Reviewed

Variable	Category	Frequency n (%) N = 800	Completed n (%) N = 242	Not completed n (%) N = 558
Age	0–11 m	660 (82.5)	233 (35.3)	427 (64.7)
	12–59 m	140 (17.5)	9 (6.4)	131 (93.6)
Sex	Male	393 (49.1)	132 (33.6)	261 (66.4)

	Female	407 (50.9)	110 (27.0)	297 (73.0)
Health facility type	Confessional	458 (57.3)	180 (39.3)	278 (60.7)
	Private	18 (2.3)	5 (27.8)	13 (72.2)
	Public	324 (40.5)	57 (17.6)	267 (82.4)
Health area	Holforth	14 (1.8)	3 (21.4)	11 (78.6)
	Likomba	182 (22.8)	51 (28.0)	131 (72.0)
	Missellele	3 (0.4)	1 (33.3)	2 (66.7)
	Mutengene	424 (53.0)	174 (41.0)	250 (59.0)
	Tiko Town	177 (22.1)	13 (7.3)	164 (92.7)
Setting	Rural	341 (42.6)	60 (17.6)	281 (82.4)
	Urban	459 (57.4)	182 (39.7)	277 (60.3)

Age-appropriate Vaccination Completion

The overall age-appropriate vaccination completion was 30.3% (242/800). Vaccination completion was considerably higher among younger children, with 35.3% (233/660) of those aged 0–11 months completing their vaccination schedule, compared with only 9 (6.4%) among those aged 12–59 months. Vaccination completion was slightly higher among males (33.6%) than females (27.0%). The highest proportion of completed vaccination was observed among children attending confessional health facilities (39.3%). Incomplete vaccination was most common among children attending public facilities (82.4%). Vaccination completion was substantially higher among urban children (39.7%) than among rural children (17.6%) (Figure 1).

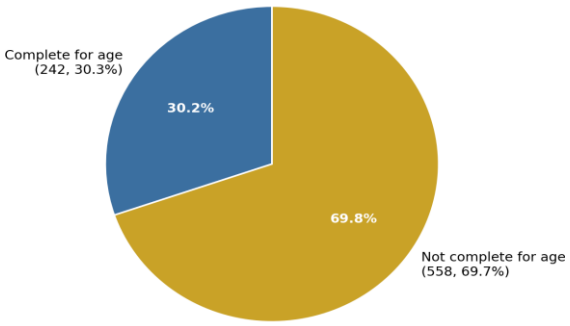


Figure 1. Pie Chart Showing Age-appropriate Vaccination Completion (N = 800)

Prevalence of Timely Vaccination among those Who Received the Vaccines

Overall, vaccination coverage declined progressively with subsequent doses in the immunisation schedule. BCG vaccine had the highest coverage, with 789 (98.6%) children vaccinated. However, only 356 (45.1%) of the vaccinated children received the vaccine within the recommended time. Pentavalent vaccine dose 1 was received by 608 (76.0%) children, and notably, all vaccinated children received the vaccine within the recommended age interval. Coverage declined for Pentavalent dose 3, with 385 (48.1%) children vaccinated, among which 367 (95.3%) received the vaccine on time. Vaccination coverage was particularly low for the measles-rubella vaccines. Only 72

(9.0%) children had received the first dose of the measles-rubella vaccine, although 70 (97.2%) of those vaccinated received it within the recommended age. Similarly, only 2 (0.3%) children had received the second dose of the measles-rubella vaccine, and both vaccinations were administered on time (Table 3).

Table 4. Prevalence of Timely Vaccination

Vaccine	Vaccinated n (%)	Timely n (%)
BCG	789 (98.6)	356 (45.1)
Penta 1	608 (76.0)	608 (100)
Penta 3	385 (48.1)	367 (95.3)
MR 1	72 (9.0)	70 (97.2)
MR 2	2 (0.3)	2 (100)

Factors Associated with Untimely Routine Vaccination among Caregivers

The analysis in this section draws on the second data source described in the Methods, the household survey of primary caregivers (n ≈ 604) rather than the facility record review (N = 800) used in sections 4.1 and 4.2. This sub-sample was used because vaccination reminders, caregiver knowledge, and other caregiver-reported determinants examined here were captured only through the household survey instrument.

In the bivariate logistic analysis, caregiver education, age of child under five years, knowledge of the routine immunisation schedule, receipt of vaccination reminders, and waiting conditions at the vaccination clinic showed statistical significance.

In the adjusted multivariate analysis, knowledge of the routine immunisation (RI) schedule, receipt of vaccination reminders, and age of child under five years remained independently associated with untimely routine childhood vaccination. Caregivers who lacked knowledge of the RI schedule had over four times higher odds of untimely vaccination compared with those who were knowledgeable (aOR = 4.3, 95% CI: 2.41–7.92; p<0.001). Likewise, caregivers who did not receive vaccination reminders had more than twice the odds of untimely vaccination compared with those who received reminders (aOR = 2.2, 95% CI: 1.30–3.66; p = 0.003). Age of child under 5 years showed a complete reversal after adjustment because of confounding. Children aged 0-11 months had approximately 3.2 times the adjusted odds of untimely vaccination compared with children aged 12-59 months (aOR = 3.22, 95% CI: 1.26-8.26; p = 0.015).

Although caregivers with low education had higher odds of untimely vaccination than those with higher education, the association was not statistically significant after adjustment (aOR = 1.5, 95% CI: 0.89–2.47; p = 0.127). Similarly, age group, place of residence, and satisfaction with waiting conditions were not independently associated with untimely vaccination. Caregivers aged <30 years had similar odds of untimely vaccination compared with those aged ≥30 years (aOR = 0.99, 95% CI: 0.61–1.61; p = 0.975), while residence in Mutengene was not associated with untimely vaccination compared with Tiko (aOR = 0.96, 95% CI: 0.54–1.72; p = 0.810). Likewise, dissatisfaction with waiting conditions was not significantly associated with untimely vaccination (aOR = 2.2, 95% CI: 0.61–7.64; p = 0.231).

Occupation, distance to the nearest vaccination center, overall patient satisfaction, and health worker communication were not significantly associated with untimely routine childhood vaccination in the bivariate analysis and were therefore not retained as independent predictors (Table 4).

https://doi.org/10.21522/TIJAR.2014.13.04.Art014

Table 5. Bivariate and Multivariate Analysis of Factors Associated with Untimely Routine Immunisation Childhood Vaccination

Variable	Category	Timely n (%)	Untimely n (%)	cOR (95% CI)	P	aOR (95% CI)	P
Age group	≥30	242 (84.3)	45 (15.7)	1		1	
	<30	273 (86.4)	43 (13.6)	0.8 (0.54–1.33)	0.546	0.99 (0.61–1.61)	0.975
Education	High	361 (87.2)	53 (12.8)	1			
	Low	154 (81.5)	35 (18.5)	1.5 (0.97–2.47)	0.085	1.5 (0.89–2.47)	0.127
Residence	Tiko	390 (84.8)	70 (15.2)	1			
	Mutengene	125 (87.4)	18 (12.6)	0.8 (0.46–1.39)	0.521	0.96 (0.54–1.72)	0.810
Age of child months	12–59 months	16 (66.7)	8 (33.3)	1			
	0–11 months	499 (86.2)	80 (13.8)	0.3 (0.13–0.77)	0.018	3.22 (1.26–8.26)	0.015
Occupation	Employed	304 (84.7)	55 (15.3)	1			
	Unemployed	211 (86.5)	33 (13.5)	0.8 (0.54–1.38)	0.620	—	—
Distance	≤5 km	277 (86.0)	45 (14.0)	1			
	>5 km	238 (84.7)	43 (15.3)	1.1 (0.71–1.75)	0.730	—	—
Knowledge of RI schedule	Yes	474 (88.1)	64 (11.9)	1		1	
	No	39 (61.9)	24 (38.1)	4.6 (2.6–8.1)	<0.001	4.3 (2.41–7.92)	<0.001
Reminders	Yes	402 (88.0)	55 (12.0)	1		1	
	No	113 (77.4)	33 (22.6)	2.1 (1.32–3.45)	0.003	2.2 (1.30–3.66)	0.003
Patient satisfaction	Satisfied	510 (85.4)	87 (14.6)	1			
	Not satisfied	5 (83.3)	1 (16.7)	1.2 (0.14–10.16)	1*	—	—
Waiting conditions satisfactory	Yes	503 (85.7)	84 (14.3)	1		1	
	No	10 (71.4)	4 (28.6)	2.3 (0.73–7.81)	0.135*	2.2 (0.61–7.64)	0.231
HW communication	Always	497 (85.7)	83 (14.3)	1			
	Not always	13 (76.5)	4 (23.5)	1.8 (0.59–5.79)	0.509	—	—

Note: *(n, number of participants; cOR, crude odds ratio; aOR, adjusted odds ratio; * Fisher's exact test)*

Discussion

Age-appropriate Vaccination Completion

This study revealed substantial gaps in routine age-appropriate vaccination completion in the Tiko Health District. Although initial vaccine uptake was high, only 30.3% of children were classified as having completed age-appropriate vaccination. Antigen-specific coverage showed a progressive decline across the vaccination continuum, from 98.6% for BCG and 76.0% for Penta1 to 48.1% for Penta3. This pattern indicates that the principal challenge is not necessarily initial contact with immunisation services, but rather retention of children through successive vaccination contacts.

This finding is consistent with Yakum et al., who reported that only 37% of children aged 12–59 months were fully vaccinated across six health districts in Yaoundé, while 16% were zero-dose [8]. The authors also reported BCG coverage of 78%, illustrating persistent gaps in routine immunisation completion in Cameroon. Although the magnitude of vaccination

completion differed between the two studies, both demonstrate that high initial contact with immunisation services does not necessarily translate into completion of the recommended series. This study therefore adds evidence from the Tiko Health District that continuity of vaccination remains an important programme challenge, even where initial vaccine uptake is relatively high. Recent WHO/UNICEF estimates for Cameroon similarly indicate persistent differences between initial and subsequent vaccine doses [6], reinforcing the need to focus not only on access to the first vaccine dose but also on retention throughout the vaccination schedule. It is worth noting that the six health districts studied by Yakum et al., were located in Yaoundé, an urban_setting, whereas Tiko is a semi-urban district; this contextual difference in setting should be considered when interpreting the comparison between the two studies.

The decline from Penta1 to Penta3 is particularly important. Penta1 coverage was 76.0%, compared with 48.1% for Penta3, representing a substantial loss of children between the first and third doses. This pattern suggests that opportunities to establish initial contact with caregivers are not being translated into sustained attendance. Possible explanations include missed appointments, competing household responsibilities, inadequate reminder and recall mechanisms, and insufficient follow-up of children who fail to return. A comparable pattern has been documented elsewhere in Cameroon: Ateudjieu et al. (2020), using administrative register data in the neighbouring Foumban Health District (West Region), reported a general dropout rate of 50.0% between BCG and measles-rubella vaccination [18], suggesting that substantial attrition across the vaccination continuum is not unique to Tiko but reflects a broader sub-national programmatic challenge. Part of the difficulty in benchmarking such attrition may also stem from definitional inconsistency: in a scoping review covering 103 low- and middle-income countries, Wariri et al. (2022) found no consistent standard for defining or measuring vaccination timeliness and completion across studies [19], underscoring the need for harmonised indicators when comparing performance across districts such as Tiko.

Prevalence of Timely Vaccination

Vaccination timeliness also varied substantially across antigens. Despite the very high BCG coverage (98.6%), only 45.1% of BCG-vaccinated children received it within the recommended period. In contrast, 100% of Penta1 and 95.3% of Penta3 recipients were vaccinated on time. This apparent contrast between high timeliness among children who received later doses and declining overall coverage is important. It suggests that among children who remained connected to vaccination services, vaccination was generally delivered within the expected period.

These findings differ from those of Chiabi et al. at the Yaoundé Gynaeco-Obstetric and Paediatric Hospital, where BCG coverage reached 99.8% and 83.2% of BCG vaccinations were timely; timeliness was also above 93% for vaccines scheduled at 6 and 14 weeks [9]. Differences in service accessibility, study population, and health-service organization may partly explain this variation. More importantly, the high timeliness observed for Penta1 and Penta3 among vaccinated children in Tiko, despite the sharp decline in coverage, suggests that retention and completion of the vaccination series — rather than timeliness among children who remain engaged with services — constitute a major programmatic challenge.

Caregiver knowledge of the routine immunisation schedule emerged as the strongest independent factor associated with untimely vaccination. Children whose caregivers lacked knowledge of the schedule had more than four times higher odds of untimely vaccination (aOR = 4.3; 95% CI: 2.41–7.92; $p<0.001$). This finding suggests that

knowledge of when vaccines are due may be more directly relevant to timely utilisation of vaccination services than general awareness of immunisation alone. This finding is strongly supported by Ngandjon et al. in Foumbot, Cameroon, who found that parents who were aware of the vaccination schedule were 3.52 times more likely to have fully vaccinated their children (OR = 3.52; 95% CI: 1.43–8.65) [10]. Their study also reported 60% vaccine acceptance and identified poor knowledge of vaccine-preventable diseases as an important concern.

These findings highlight caregiver knowledge as a modifiable determinant and support strengthening health education and systematic communication of the next vaccination appointment at every contact. This finding has an important programmatic implication: providing vaccination at the health facility alone may be insufficient if caregivers do not clearly understand which vaccine is due, when it is due, and when they should return.

The absence of vaccination reminders was also independently associated with untimely vaccination (aOR = 2.2; 95% CI: 1.30–3.66; p = 0.003), indicating that reminder and recall mechanisms could play an important role in maintaining children within the vaccination continuum. This finding aligns with the meta-analysis of Harvey, Reissland and Mason (2015), who found, across 28 trials involving nearly 15,000 parent-child dyads, that reminder and recall interventions significantly increased childhood immunisation uptake [20]. Evidence specific to phone-based reminders, however, remains more heterogeneous: Eze, Lawani and Acharya (2021), in a meta-analysis of 18 studies from low- and middle-income countries, reported a positive effect of SMS reminders on vaccination coverage and timeliness [17], whereas Yunusa et al. rated the overall quality of evidence for mobile phone reminders as low to moderate, with effects on timeliness often statistically non-significant [21]. This suggests that reminder strategies, and their mode of delivery, may need to be locally adapted and validated rather than assumed to be uniformly effective in the Tiko context. The number of children under five years in the household was also independently associated with untimely vaccination (aOR = 3.22; 95% CI: 1.26–8.26; p = 0.015), potentially reflecting competing childcare and household responsibilities. Conversely, caregiver education was not independently associated with timeliness after adjustment (aOR = 1.5; 95% CI: 0.89–2.47; p = 0.127). This contrasts with Yakum et al., who found that maternal education was strongly associated with full vaccination, with children of mothers with higher education having substantially greater odds of being fully vaccinated (OR = 8.25; p = 0.0018) [8]. The difference may suggest that, in Tiko, specific knowledge of the vaccination schedule is more influential for timeliness than formal educational attainment itself.

Overall, the findings indicate that routine immunisation performance in Tiko is characterised by high initial access but inadequate retention and completion across the vaccination continuum. This interpretation is consistent with both recent Cameroonian empirical evidence and WHO/UNICEF vaccination estimates. Strengthening caregiver knowledge, reminder and recall systems, defaulter tracking, community outreach, and routine monitoring of vaccination dropout should therefore be prioritised to improve vaccination completion and timeliness in the Tiko Health District.

Risk Factors Associated with Untimely Routine Childhood Vaccination

The study identified several caregiver- and household-related factors associated with factor associated with untimely routine childhood vaccination. In the adjusted analysis, poor caregiver knowledge of the routine immunisation schedule was the strongest factor associated with untimely vaccination

(aOR = 4.3; 95% CI: 2.41–7.92; p<0.001), while lack of vaccination reminders was associated with more than twice the odds of delayed vaccination (aOR = 2.2; 95% CI: 1.30–3.66; p = 0.003).The age of child under five years in the household was also significantly associated with vaccination timeliness (aOR = 3.22; 95% CI: 1.26–8.26; p = 0.015), suggesting that competing childcare responsibilities may affect adherence to vaccination schedules.

In contrast, caregiver age, education, residence, occupation, distance to vaccination services, satisfaction, and waiting conditions were not independently associated with untimely vaccination after adjustment. These findings highlight caregiver knowledge, reminder systems, and household responsibilities as key areas for interventions aimed at improving vaccination timeliness and completion. These associations should nonetheless be interpreted with some caution, as several explanatory variables including knowledge of the immunisation schedule and receipt of reminders relied on caregiver report. Modi et al. (2018), in a systematic review of recall quality in low- and middle-income settings, found that caregiver recall of vaccination-related information is often imperfect and can both overestimate and underestimate true vaccination behaviour [16], suggesting that triangulation with documented records, where feasible, would further strengthen future assessments of these determinants in Tiko.

Strengths and Limitations

Strengths: The relatively large sample of 800 vaccination records strengthened the assessment of vaccination coverage, completion, and timeliness. Importantly, assessing timeliness alongside vaccination completion provided additional insight into whether children received vaccines at the recommended ages. Multivariable analysis also enabled the identification of key modifiable factors associated with untimely vaccination.

Limitations: The cross-sectional design limited the ability to establish causal relationships between identified factors and vaccination outcomes. The purposive selection of health facilities and because no formal sample size calculation was performed, may also limit the generalisability of the findings to the entire Tiko Health District. In addition, caregiver-reported vaccination information, when vaccination cards were unavailable, may have introduced recall bias. Finally, because 82.5% of children were aged 0–11 months, coverage estimates for vaccines scheduled later in childhood, particularly MR2, should be interpreted cautiously, as many children had not yet reached the eligible age.

Conclusion

Routine childhood immunisation in the Tiko Health District shows high initial uptake but substantial attrition across subsequent doses, leaving age-appropriate completion low. Caregiver knowledge of the schedule and receipt of reminders were the strongest modifiable predictors of timeliness. Strengthening caregiver communication, reminder and recall systems, and defaulter tracking should be prioritised to improve completion, timeliness, and equity in the district.

Data Management

Survey data were not accessible to participants at participating health facilities. Responses were transmitted electronically to KoboCollect, linked to the investigator's account. Access to the dataset was restricted to the study statistician for analysis. Participants were identified using unique study identification numbers, and direct identifiers were excluded from the analytical dataset. Regular secure backups of exported datasets were maintained separately from the primary database.

Competing Interests

The authors declare no competing interests.

Acknowledgements

The authors sincerely acknowledge the Tiko Health District Management Team and the participating health facilities for facilitating the implementation of this study. We also thank the healthcare workers, research assistants, parents, and caregivers who contributed their time and experiences to the research. Their cooperation and participation were invaluable to the completion of this study.

Ethical Approval

Ethical clearance was obtained from the Regional Ethics Committee for Human Health Research of the Southwest Region of Cameroon (04/CRERSH/SW/C/02/2026). Authorisations were sought from the Southwest Regional Delegation of Public Health (P42/MINSANTE/SWR/RDPH/RCB.PT/04/2026), the Regional EPI Officer Southwest (P12/MINSANTE/SWR/RDPH/EPI/), and Tiko Health District (N°2026/28vol/MINSANTE/RDPHSW/THD/504). All procedures involving human participants were conducted in accordance with the ethical standards of the institutional and national research committees and in compliance with the principles of the Declaration of Helsinki. Written informed consent to participate was obtained from all study participants before data collection.

Authors' Contributions

N.B.C.P., T.R., O.E.A and D.A. participated in the study design. N.B.C.P. oversaw pilot testing and data collection. N.B.C.P., T.R., O.E.A., and D.A. contributed to the writing and review of the manuscript and approved the final version. N.B.C.P, T.R., O.E.A and D.A. assisted in statistical analysis and interpretation of results. N.B.C.P. had overall responsibility for the study design, overseeing survey distribution, and interpretation of results.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data Availability

The datasets generated and analysed in this study are not publicly available due to institutional regulations but can be obtained from the corresponding author upon reasonable request. All data access requests will be subject to review by the Ethics Committee of the Cameroonian Ministry of Public Health and the Regional Ethics Committee for Human Health Research for the South West Region, to ensure adherence to ethical and legal requirements.

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https://doi.org/10.21522/TIJAR.2014.13.04.Art015

Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art015

ISSN: 2520-3088
Volume 13 Issue 4, 2026

How Digital Marketing is Changing the Traditional Marketing Mix

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Cite this article as: Rajesh Ramsudeen. How Digital Marketing is Changing the Traditional Marketing Mix. Texila Int J Acad Res. 2026;13(4). https://doi.org/10.21522/TIJAR.2014.13.04.Art015

Article Type: Original Research

Received: 02.09.2026

Accepted: 08.10.2026

Published: 30.10.2026

Abstract *This paper examined how digital marketing has transformed the traditional marketing mix to the digital marketing mix, moving businesses from company-focused and one-way marketing toward more interactive, customer-centered, and data-driven strategies. Using the traditional 4 Ps—product, price, place, and promotion—and the extended 7 Ps framework, the paper compares traditional marketing with modern digital marketing. Digital technologies such as artificial intelligence, big data, machine learning, e-commerce, personalization, and social media have transformed each element of the marketing mix. Products can now be digitally customized and continuously improved, prices can be adjusted using real-time data, distribution has expanded through online and omnichannel platforms, and promotion has become more interactive through social media, SEO, and content marketing. The additional 3 Ps-people, process, and physical evidence have also evolved. Businesses now build online communities, automate customer service through CRM and AI, and use websites, apps, reviews, and digital credentials to establish trust and credibility. Overall, the paper concludes that digital marketing has changed the marketing mix from a static, traditional tool into a dynamic and continuously adaptable strategic framework. While digital marketing provides benefits such as global reach, personalization, cost efficiency, and better customer insights, it also creates challenges involving cybersecurity, data privacy, misinformation, and increased competition. Therefore, businesses need to adopt a flexible, integrated, and ethical digital marketing strategy to maintain customer trust and achieve long-term competitive advantage.*

Keywords *Digitalization, Digital Marketing, Marketing Mix, Traditional Marketing.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art015

Introduction

In today's dynamic business environment, the pace of doing business is changing at a rapid rate. The advancement of digital technologies is imperative for organizations operating in either the global marketplace, or for companies operating domestically. The advent of digital transformation has become a major area of business innovation and revolution. Digital marketing and technologies have changed the dynamics of traditional marketing worldwide, especially the method marketers have used the marketing mix. Subsequently, Neil Borden coined the term "marketing mix" and McCarthy in 1964 defined the 4 Ps marketing mix as an assortment of all the characteristics which marketing managers would use to meet the needs of a particular market. The business environment worldwide has experienced numerous revolutionary changes with the introduction of new concepts such as digital marketing. The integration of technology could result in a universal shift in market participants/ customer behavior and competing strategies [1].

Researchers [2] defined marketing mix as "the set of tactical marketing tools that the firm blends to produce the response it wants in the target market". The early theory of the marketing mix, which transferred into the four traditional P 's of marketing, which includes Product, Price, Promotion, and Place. This paper will examine how the modern era of marketing has affected the traditional marketing mix, by a detailed investigation on how digital marketing has changed the global landscape of the dynamism of today's marketing environment.

Aim of Research

The aim of this study is to investigate the traditional marketing mix and the digital marketing mix, and the role it plays in today's evolutionary business environment.

Objectives

1. To identify the main elements of the traditional marketing mix and the digital marketing mix, and their role.
2. To examine the benefits and drawbacks of the digital traditional and digital marketing mixes.
3. To discuss the main facets of the marketing mix and the traditional marketing mix.

Data Collection

The data collected for this study consist mainly of secondary data on the topic area, and extensive and comprehensive search of the literature reviewed together with key analytical reports on the subject.

Methodology

This study was conducted by utilizing reports, and secondary research on the topic area. This was accomplished by accumulating and examining current and previous information on the subject, the data generated research outcomes which would grant the study major benefits. Both the traditional and digital marketing mix was diagnosed to extract valuable insights on the topic being investigated.

The Marketing Mix

The marketing mix as explained by Kolter, Armstrong and Mc Carthy which are the traditional four P's of marketing, product, price, place and promotion, from traditionally the 4 P's the mix has seen an extension for the services sector. The marketing mix has evolved into the services sector, these include physical evidence, people and processes. This view is also supported by Extension, Special, Dheere [3] illustrating that "People, Process, and Physical Evidence, serve as a guide for businesses aiming to optimize their offerings and enhance customer satisfaction". These additional P's are dedicated to the services sector in marketing.

https://doi.org/10.21522/TIJAR.2014.13.04.Art015

Marketing strategies, this element within organizations, is all about identifying and finding out the wants and needs of the customers by creating products, promotions, prices, and places (marketing mix) that answer those needs and wants of the customer. The 4Ps of marketing as mentioned are product, price, place and promotion, these factors are very popular among the marketers. The place is used to designate a product's online or physical placement. The product, event, or brand is promoted through communications with target consumers within the marketing mix, this is also known as Promotion. Regarding the products, it relates to a product's characteristics, advantages, designs, presenting, and branding. These are significant components of the organization's marketing plan. Price is how much a customer is willing to spend on a good [4].



Traditional Marketing Mix

Product, this applies to the goods the organization is offering to your customers. Besides the physical product itself, there are factors related to the product that customers could be attracted to, this can be the design, or packaging. Further product attributes involve the quality, features, options, services, warranties, and brand name of the products themselves. The product's appearance, features, function, and support make up what the customer is essentially purchasing. [5]. Successful organizations and marketers thoroughly focus on the customer needs/ wants that their product offerings are designed to satisfy, by recognizing the importance of designing products that effectively address customer needs.

Price, this refers to the amount customers are willing to pay for the product. This P is considered a very significant element of the marketing mix. Setting the correct price can be very challenging because it involves careful understanding of several factors, these include customer demand, market, production costs, consumers' purchasing power, competitors' pricing, and government regulations. The element of pricing within the mix is a critical organizational decision as it subsequently directly affects both the demand for a product and the overall profitability of the firm. Additionally, Price establishes the target consumer market as well as the strategy for advertising, promotion and distribution for the

product. Pricing the product communicates real value to the customers and this can have direct impact on the firm's performance. The impact on pricing depends on the elasticity of the product [6].

Place, this element of the marketing mix refers to the location, decisions and strategic distribution, this is where the product can directly reach the target market [7]. This process involves a network of individual and intermediary institutions, including distributors, wholesalers, and retailers, collectively referred to as the firm's distribution channel. Organizations determine the most appropriate distribution strategy, such as supplying products directly to retailers, utilizing distributors or wholesalers, or adopting a direct-to-consumer approach. The choice of distribution channels depends on the firm's marketing objectives, operational capabilities, and target market.

Promotion, this element of the marketing mix refers to the marketing activities that are embarked on to raise understanding/ awareness and inform customers particularly to the target market, as well as to foster sales of the products being sold [8]. Promotion is an important ingredient of the marketing mix because it comprises informing, persuading, and influencing consumers to choose the product being promoted. Organizations promote their products via personal selling, publicity, advertising, and sales promotion through major communications. The principal purpose of promotion is to provide prospective customers with information about a product's availability, benefits and features. promotions also aid in generating consumer interest, pushes comparisons with competing products, and supports informed purchasing decisions. The rapid growth of both print and digital media has substantially enhanced the effectiveness and reach of promotional activities via numerous communication channels.

People, this element of the extended mix, according to [9] stated that 'all human actors who play a part in service delivery and thus influence the buyers' perceptions; namely, the firm's personnel, the customer, and other customers in the service environment'. Anyone (people) who interacts with an organization's customers plays a role in shaping their experience. These interactions can leave either a positive or negative impression, significantly influencing customer satisfaction. Since the business' reputation is essentially built through these customer interactions, employees (people) must be appropriately trained, motivated, and possess the right attitude to consistently deliver excellent service.

Physical Evidence, physical facilities also support the marketing of a product, physical facilities can influence consumers to use the product or services offered. These include physical buildings, logos and residents [10]. Physical evidence, this factor within the marketing mix implies to the setting where a service is delivered to and experienced by the customer. This environment of the service encompasses a selection of elements that can shape customers' perceptions of the service experience. These aspects include the ambience, such as temperature, scents, colors, lighting, sounds, and music, all of which influence to the overall atmosphere of what is being offered to the service. Additionally, the spatial functionality and layout of the environment such as the layout of furniture, equipment, and other physical features, this plays a significant role in influencing customer comfort, convenience, and overall satisfaction of the service provided by an organization.

Processes, component of the marketing mix, imply the flow of activities involved in the process of delivering the service to the consumer [11]. The approach services are delivered, along with the behavior of the employees providing service, plays a significant role in establishing customer satisfaction. Influences such as the quality of information revealed with customers, waiting times and the willingness of employees to assist

all contribute to a positive customer experience. Firms aim to deliver a seamless, efficient, and customer-focused service journey, which is determined by a well-designed process operating behind the scenes to guarantee consistent and effective delivery service to the customer by the organization's process.

The Digital Marketing Mix

The digital marketing mix is a key strategy that is used by marketers to promote their products or services, this encourages consumers' purchase intentions. Digital marketing enhances marketing effectiveness and contributes to improved business performance and profitability. Digital channels also provide cost-efficient ways for businesses to build strong relationships with consumers, strengthen customer engagement, and foster long-term loyalty [12]. The evolution of digitalization is transforming the method marketing strategies are developed and implemented, marketers and producers of products and services are overall reshaping the marketing mix management to meet customer needs [13]. Digital marketing transformation has reinvigorated a shift in both theoretical and practical aspects of marketing, making strategic activities such as customer segmentation, market analysis, and the customization of the marketing mix more efficient and achievable. This development has also reinforced the critical role of marketing in enhancing an organization's competitiveness and overall success.

Product, product customization and interactive promotions play a key role in the digital marketing mix by allowing businesses to adapt their products and services to meet consumer preferences while increasing customer engagement through online interactions [14]. Today's products are increasingly designed around customer needs rather than being driven into the market of the old (traditional). The information age of digitalization has made consumers more learned and informed also very demanding, while quicker product life cycles require firms to deliver products on a timely manner, relevant, appropriate and well-targeted. As a result, decreasing the time it takes to bring new products to market has become a strategic factor in achieving business/ product success. The digital era has significantly enhanced product development and design capabilities, enabling innovations and improvements that were previously unimaginable [15].

In a digital environment, the view of a product (s) goes way beyond just the physical or digital item itself to incorporate the overall user experience, interface design, and the methods digital technologies enhances how products are delivered. [16] argued that the "differentiation between the "core product" and the "extended product," explaining that e-commerce businesses often provide additional information and services, such as order tracking, to increase the value of the core offering". Digital platforms facilitate the "dematerialization" of products by transforming physical products into digital services. For instance, books are now available in numerous formats, these include e-books, audiobooks, representing how one core product can be modified into different digital formats to accommodate various consumer needs and preferences [17].

Variety of products of different categories can be made available to customers. Companies can use various tools that allow businesses to configure and modify preferred product components. Products listed on an organization's website can also be made accessible via search engine shopping platforms, such as Google and Yahoo. Product prices can be adjusted vigorously in response to changes in supply and demand for the product. Additionally, marketers can identify target prices for preferred product offerings, facilitating the business website to identify and display suitable products from the organization's portfolio.

Price, this element of the marketing mix is deeply connected to the business model, The rapid progression of digital technologies, in particular, artificial intelligence, big data analytics, machine learning, and has significantly enhanced organizations' capacity and capabilities to develop and implement dynamic pricing mechanisms. These technologies facilitate firms to analyze real-time consumer behavior, market environment, and demand patterns, thereby facilitating the constant adjustment of prices in response to environmental changes in consumer preferences and market dynamics. Pricing strategies within the contemporary digital marketing environmental paradigm have experienced fundamental evolutional shifts from conventional product-centric models toward methods that emphasize the creation and communication of personalized customer value.

Traditional pricing mechanisms, including cost-based and competitor-oriented pricing, are increasingly perceived as insufficient for addressing the complexity, heterogeneity, and rapidly evolving nature of digital consumer behavior. Consequently, value-based pricing (VBP) has gained prominence as a more strategically appropriate and comparatively superior approach for navigating contemporary digital marketplaces [18]. Within the digital ecosystem, price is no longer conceptualized merely as a quantifiable economic variable; rather, it constitutes a multidimensional signal of perceived value that is constructed, communicated, and reinforced across diverse digital touchpoints, customer interactions, and experiential contexts [19].

Place, (distribution) in the digital age, this concept has expanded to include various forms of e-commerce and online distribution. These include e-commerce platforms, online marketplaces, multichannel retailing, mobile commerce, virtual stores and showrooms, as well as online payment gateways [20]. This type of distribution ascertains marketing channels, direct sales the most effective means/ methods for the online business environment, sales are completed via cyber intermediaries, sales through online telemarketing, direct sales via e-mail [21]. Furthermore, the place (distribution) element of the digital marketing mix incorporates digital environments that function as multifaceted structural hubs for businesses, facilitating a wide range of activities including online presence, customer engagement, product and service distribution, and operational support. In the present contemporary and existing business contexts, digital platforms progressively transcend their traditional role as distribution channels, serving simultaneously as critical infrastructural foundations that underpin organizational operations. This is particularly evident in the case of social media platforms and electronic marketplaces, which facilitate not only market access and customer interaction but also broader dimensions of business coordination and service delivery [22].

Promotion, this factor of the digital marketing mix refers to the numerous forms of marketing communication organizations used to inform and influence their customers on products or services. In digital marketing, this involves content marketing, advertising, social media, paid search and display, and marketing automation. The most efficient and effective combination of these channels largely be determined by whether the target audience consists of business B2B or individual consumers B2C [23]. Furthermore, this type of digital promotion involves the use of digital and online platforms to market products, services, brands, or content to a specific target audience. It utilizes the internet, email, social media, websites, search engines, and other online channels to engage and reach potential customers by sharing information about the product or service. Key components include social media marketing, email marketing, content marketing, search engine marketing, messenger marketing, and voice marketing.

People, within this element in the digital marketing mix, people may be understood as the human actors whose behaviors, expertise, communication practices, and relationship-building capabilities shape the creation, delivery, and interpretation of value across the digital touchpoints of the firm. This involves the organization's employees responsible for managing websites, social media platforms, online communities, customer relationship management systems, and digital advertising activities, as well as customers and other external stakeholders who actively contribute to the process of value creation. The significance of this element within the digital marketing mix stems from essentially the interactive nature of digital environments, this is where human engagement and interpersonal interactions play a critical role shaping the customer experiences and perceptions of value of the organization.

Regarding the people dimension of the digital marketing mix pertains to the business ability to foster significant meaningful, reciprocal, and customer-responsive relationships through digital communication channels. These digital platforms, social networking sites, online communities, review forums, and instant messaging services, facilitate direct and interactive communication between customers and organizations, while simultaneously enabling customers to exchange information, experiences, and opinions with one another.

Place, In the present digital age, this concept place within the digital marketing mix has expanded to integrate various forms of e-commerce and several online distribution channels. These include e-commerce platforms, online marketplaces, multichannel retailing, mobile commerce (m-commerce), virtual stores and showrooms, digital distribution networks, and online payment gateways [24]. Further examination in this field indicates that place (online distribution) establishes marketing channels such as direct sales, which are particularly effective in the online environment; sales through cyber intermediaries, online telemarketing; and direct sales via email. Additionally, another option is to use vertical hubs, which are developed through commercial partnerships with organizations operating within a specific industry or sector [25].

Physical Evidence, this component of the digital marketing mix, encompasses the tangible and perceptible elements that impact the establishment of consumer trust, corporate credibility, and brand image. Within the context of digital marketing, physical evidence continues beyond conventional physical attributes to encompass both tangible and digital touchpoints. These incorporate environmental elements, such as the physical layout of a store or the design and functionality of a website; tangible cues, including product packaging, brochures, and employee uniforms; and an organization's online presence, reflected through its website and social media platforms. Additionally, branding materials, such as logos, visual content, customer testimonials, and online reviews, serve as important indicators of brand identity and credibility. Collectively, effective physical evidence can enhance brand recognition, reinforce consumer confidence, and provide a business with a distinctive competitive advantage within the marketplace. Further to this, according to [26] illustrated that a "well-designed and user-friendly website, social media profiles, online reviews and customer testimonials can act as virtual physical evidence which provides customers with information and reassurance about the brand".

Discussion

The development of a coherent digital marketing mix represents a critical strategic requirement for organizations seeking to maximize the efficacy of their online communication channels and attain predefined marketing objectives. The systematic alignment of established marketing mix principles with organization's digital content strategy can

substantially enhance the performance, coherence, and overall effectiveness of its digital platforms. In contrast, the absence of such strategic alignment may give rise to fragmented, inconsistent, or incongruent online content, thereby increasing the likelihood of consumer uncertainty and adversely affecting brand perceptions, purchase evaluations, and, ultimately, consumer purchasing behavior.

More recent scholarly reviews indicate that a generally established model of the digital marketing mix has yet to emerge in recent times. Existing frameworks comprehend a diverse scope of dimensions, including personalization, privacy, customer service, online communities, security, and website functionality. Researchers including, [27] identify a broad range of the digital marketing-mix models and advocate for a consolidative perspective that synthesizes conservative marketing-mix elements with factors that are distinctive to the digital environment.

The absence of theoretical agreement is particularly substantial, as it challenges the conceptualization of the digital marketing mix as a standardized or prescriptive checklist. Moreover, this may be more suitably conceptualized as an adaptive strategic framework whose essential elements and relative importance are contingent upon an organization's industry context, target market, business model, and prevailing technological environment.

The digital marketing environment introduces a multiplicity of complex considerations that encompasses beyond the instructive scope of the traditional marketing framework, encompassing privacy protection, cybersecurity, data governance, algorithmic transparency, and very importantly consumer trust. These dimensions assume particular significance given the extent to which contemporary digital marketing practices rely upon the systematic collection, processing, and analysis of consumer data. Subsequently, an exclusively tactical conceptualization of the marketing mix may inadequately account for the broader institutional, regulatory, and ethical conditions that underpin the legitimacy, resilience, and long-term sustainability of digital marketing practices.

Further aspects of some drawback relating to digital marketing can be misleading, pictures, figures and images are misleading in this digital media, and some business activities are thieves who steal other online marketing undertakings. Furthermore, digital competitions are becoming progressively challenging in this field. While established promoters can develop healthy and successful competitions, whiles small and newly established promoters frequently struggle to compete effectively. As a result of this, the growing influence of digital media has become a drawback for emerging businesses and advertisers, leading to financial losses and making it more difficult for them to grow. Additionally, safety system customers or buyers may not obtain proper answers or solutions when they have questions about a product or service. This is because digital marketing activities are often achieved within certain limitations, resulting in insufficient product information being provided through digital media channels [28].

Even though these are some drawbacks relating to the digital marketing mix, the examination below illustrates the grate deal of advantages, and positive effects it can have in today dynamic business environment.

The exponential advancement of digital technologies in the modern era has catalyzed a paradigm shift in organizational communication strategies, promotional paradigms/ concepts, and value-creation mechanisms within progressively hyper-competitive market landscapes in both localized and international markets. Conceptually, digital marketing comprises the strategic deployment of digital technologies, media platforms, communications channels, and data analytics to engage contemporary target audiences while accelerating broader

organizational objectives. Diverging significantly from conservative promotional paradigms, digital marketing empowers businesses to establish consumer connections, especially interactions characterized by empirical measurability, granular personalization, real-time immediacy between the customer and the firm, and multi-directional interactivity. Consequently, the digital marketing mix has emerged as an indispensable analytical and tactical framework, facilitating organizations to systematically synthesize disparate digital initiatives to undertake cohesive strategic and operational outcomes.

The digital marketing mix forms the conceptual adaptation and transformation of the foundational marketing-mix paradigms into what is now referred to the electronic environments. While traditional strategies conventionally center upon the classic four-pillar framework comprising of standard product, price, place, and promotion, service-oriented enterprises regularly augment this construct to include the human capital, procedural architecture, and tangible service evidence these are referred as people, processes and physical evidence. Within contemporary digital ecosystems, these extended mechanisms demonstrate heightened interconnectivity, synergistically operationalized across web architectures these include social networks, search engine mechanics, mobile applications, electronic commerce platforms, targeted email protocols, digital advertising channels, customer relationship management infrastructures, and predictive data analytics. Further to this, as posited by Ref. [29], the strategic deployment of digital marketing allows businesses to systematically integrate developing technological capabilities into core marketing workflows, thereby enhancing consumer engagement mechanisms and enriching overall organizational efficacy.

A paramount advantage of the digital marketing mix vested in its capacity to transcend geographical and demographic boundaries, effectively expanding enterprise strategic scope (expanded market reach). Although conventional marketing paradigms are fundamentally restricted by physical proximity, localized distribution channels, advertising boundaries, and print circulation restrictions, digital media operates principally uninhibited by spatial boundaries. Consequently, firms can cultivate engagement across both domestic and global market segments with unprecedented ease via their communication channels. Businesses through their integration of web interfaces, search engine optimization, social media networks, electronic mail systems, and electronic commerce infrastructures, companies can facilitate continuous consumer admission to offerings regardless of geographic coordinates. This dynamic phenomenon offers outstanding utility to small and medium-sized enterprises (SMEs), as digital infrastructures democratize market access modifying the prohibitive capital expenditure historically required for international expansion. In alignment with this paradigm, [30] posit that the “pervasive integration of digital technologies has fundamentally restructured organizational engagement, enabling firms to navigate and compete within highly interconnected global marketplaces”.

An additional imperative merit of the digital marketing mix lies in the capacity for hyper-personalization (personalization of communication). Advanced digital infrastructure permits organization’s entities to dynamically calibrate marketing communications to align nuanced individual or segment-specific profiles. Diverging from huge mass-communication paradigms, companies can distribute highly contextualized content directed to distinct consumer cohort’s/ target market. An example of this, e-commerce platforms regularly leverage algorithmic predictive modeling to create suggested product recommendations taken from historical transaction data and real-time digital footprint

analysis. Similarly, automated email marketing systems methodically dispatch tailored promotional offerings informed by precise consumer interest routes, longitudinal purchase trajectories, and previous communication engagement metrics.

Further research in this topic area elucidate, contemporary customer journeys are progressively characterized by multi-touchpoint landscapes spanning from both physical and virtual domains. Synthesizing cross-channel intelligence throughout these diverse environments, this enables institutions to develop unified, seamless, and contextually salient customer experiences. Eventually, when operationalized with structural transparency and ethical data stewardship, strategic personalization substantially heightens perceived brand relevance and optimizes overall consumer satisfaction [31]. The evidence is prevalent that illustrates the digital marketing mix can put organizations at a strategic advantage in the digital modern era.

Historically, conventional marketing communications were predominantly characterized by unidirectional message communication, wherein businesses unilaterally publicized promotional content to a somewhat passive consumer base. The initiation of digital marketing mix, however, has enabled a structural shift toward bidirectional and multidirectional dialogue with the customer and the organization promoting greater customer engagement and interaction. Modern consumers actively engage with businesses by contributing to social media discourse and dialogue, submitting peer reviews, posing inquiries, sharing digital assets, contributing to virtual communities, and initiating direct brand touchpoints. This type activates heightened communicating capacity; this serves as a medium for interactive transmission and customer connection. Digital platforms, most particularly social media networks, enable organizations to conduct real-time discussions, thereby accelerating response processes for inquiries and customer complaints. As Ref. [32] illustrated, “social media has fundamentally disrupted traditional organizational-audience dynamics by empowering end-users to co-create, disseminate, and critically interact with digital content”.

Furthermore, this continuous dialogue through these digital channels functions as a rich source of qualitative intelligence (business intelligence). Analyzing user-generated content, customer critiques, and virtual conversations yields critical empirical understandings into the consumer inclinations and behavioral patterns. Therefore, businesses can leverage on these analytical inputs to iteratively enhance product offerings, service delivery, and strategic positioning of the organization’s products or service. The digital marketing mix ultimately reconceptualizes the consumer role, transforming customers from passive targets of persuasive communications into co-creators and active stakeholders within the broader marketing ecosystem.

Empirical studies also support the notion that the customer now wants to be part of the brand narrative and product design process by restructuring the marketing mix. This evolutionary course of the marketing mix is primarily reconfiguring the formulation and execution of strategic marketing paradigms, this is gearing toward the digitization of the marketing mix by precipitating a broader systemic realignment of marketing mix [33]. Consequently, contemporary market dynamics impose a revised strategic orientation specifically, digital marketing [34] alongside updated organizational architectures and core abilities of organizations. Crucially, academic discourse has intellectualized the "Marketing 4.0" framework [35] which suggests that modern consumers in the ever-changing market seek beyond functional utility, vigorously demanding integration into the value co-creation procedures and processes. This dynamic assigns a modification toward a more

collaborative, interactive, and participatory model, which Marketing 4.0 operationalizes to foster and enhance brand-consumer relationships [35].

From a policy and governance assessment, the proliferation of social media platforms in today's digital world, this has radically transformed traditional brand management practices. Consumers have arisen as central co-creators of brand story line, resulting in businesses systematically examining and evaluating user-generated content to strategically harmonize firm-led communications [36]. This has led to the emergence of the digital marketing mix, giving firms real time data measurability, global reach, cost effectiveness, efficiency and flexibility, interactive customer experiences, scalability.

Traditional Marketing Mix vs the Digital Marketing Mix

Element	Traditional Marketing Mix	Digital Marketing Mix Extension	Primary Digital Channels/Tool
Product	Physical goods, standardized lines	Digital goods, mass customization, co-creation	SaaS, digital downloads, interactive platforms
Price	Fixed pricing, seasonal sales	Dynamic pricing, freemium, subscription models	Algorithmic pricing engines, comparison sites
Place	Physical storefronts, wholesalers	E-commerce, social commerce, app stores	Marketplaces (Amazon, iOS App Store), D2C sites
Promotion	TV, print, radio, direct mail	Two-way dialogue, inbound, hyper-targeted ads	SEO, PPC, social media, Email, Influencer
People	In-store staff, sales reps	Remote support, social media teams, chatbots	Live chat, community management, CRM teams
Processes	In-person queues, manual checkout	Automated user journeys, digital fulfillment	UX optimization, payment gateways, automation
Physical Evidence	Store layout, packaging, brochures	UX/UI design, security trust seals, social proof	Trust badges, online reviews, verified ratings

The strategic evolution of the traditional marketing mix to the modern digital marketing mix marks a structural shift from a transactional, firm-centric approach to a relational, customer-centric paradigm. Viewing this phenomenon through the strategic paradigms and synthesis, it illustrates Control vs. Co-Creation, Traditional marketing highlights strong managerial command over brand messages and communication [37]. In contrast to this, digital marketing urges consumers to participate in establishing value through online communities, customer reviews, and brand advocacy [38]. Furthermore, data and analytics, traditional promotional approaches typically depend on historical information and sampling techniques, such as Nielsen ratings. Digital marketing strategies, conversely, make greater use of real-time analytics and designation models that constantly monitor consumer behavior among multiple digital channels these includes Facebook, Instagram, Tic Tok, just to name a few. Additionally, omnichannel integration, contemporary marketing strategies commonly do not treat traditional and digital marketing as competing alternatives. Instead, corporations can combine both within an omnichannel approach, using physical channels and actual brand experiences to determine credibility and trust, while digital platforms and procedures improve customer engagement and conversion efficiency.

Conclusion

The revolution of businesses from a geographically confined and comparatively

static enterprise into a vastly interconnected, data-intensive global ecosystem has displayed the restrictions of conventional marketing models when considered independently. As established throughout this research paper, digital transformation has extended beyond the mere improvement of the traditional marketing mix, rather it has essentially reshaped the scope, operational processes, and theoretical foundations. Consequently, the 7 Ps which are, product, price, place, promotion, people, process, and physical evidence, can no longer be regarded as separate, linear tactical instruments designed principally to stimulate passive consumer responses from marketing efforts from enterprises. Within the contemporary digital marketing environment, these factors operate as an interrelated and adaptive framework categorized by collaborative value creation, continuous performance optimization, dynamic interactions of value, and instantaneous consumer engagement.

As demonstrated throughout this paper, the application of the digital marketing mix creates a fair bit of strategic and ethical complexities within the marketing environment. The absence of a generally accepted and standardized academic framework underlines the inherently dynamic and context-dependent nature of the digital marketing mix, which is shaped by industry-specific circumstances, technological capabilities, and the degree of strategic amalgamation within industries. Moreover, businesses are increasingly required to address a variety of adverse implications, including algorithmic bias, data privacy violations, digital advertising fraud, deceiving or misleading digital illustrations.

The digital marketing mix has evolved, especially with the advent of the digital age. The traditional marketing mix does still have a major part to play in organization in different sectors within which they operate in. However, with the economy and the rise of artificial intelligence, the digital marketing mix will keep on evolving, which would add value to organizations that use the digital marketing mix to their advantage.

Conflict of Interest

None of the authors have any conflicts of interest to disclose.

Acknowledgement

Nil.

Ethical Approval

Ethical approval was not required for this study as it did not involve human participants. The researcher did all checks and balances before undertaking the study, as all materials were Published literature, journal articles, books, and reports.

Funding

This research received no specific grant from any funding agency.

Author Contributions

Dr Rajesh Ramsudeen contributed to the entire study, including material preparation, data collection, analysis, and writing of this paper.

Data Availability

The data supporting the findings of this study are openly available that can be viewed via the references, DOI and online.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art016

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Assessing the Policy-to-Practice Gap in the Implementation of Nutritional Guidelines for Diabetes and Hypertension in Region 3, Guyana: A Mixed-Methods Study Using the Social Ecological Model, RE-AIM and Knowledge-to-Action Frameworks

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Cite this article as: Selese Melanee Shepherd-Holder, Michael Olabode Tomori. Assessing the Policy-to-practice Gap in the Implementation of Nutritional Guidelines for Diabetes and Hypertension in Region 3, Guyana: A Mixed-methods Study using the Social sEcological Model, RE-AIM and Knowledge-to-Action frameworks. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art016**

Received: 16.08.2026

Accepted: 26.09.2026

Published: 30.10.2026

Article Type: Original Research

Abstract *Diabetes and hypertension remain major public health challenges in Guyana. The extent to which evidence-based nutrition guidelines are translated into routine clinical practice remains insufficiently understood. This study assessed the policy-to-practice gap in the implementation of nutrition guidelines for diabetes and hypertension in Region 3, Guyana. A convergent mixed-methods implementation study was conducted across four public health facilities. Quantitative data were obtained from 2,745 patient records, facility audits and healthcare provider surveys, while qualitative data were collected through focus group discussions, community outreach activities, and key informant interviews. The study was guided by the Social Ecological Model (SEM), the Reach, Effectiveness, Adoption, Implementation and Maintenance (RE-AIM) framework, and the Knowledge-to-Action (KTA) framework. Although all facilities demonstrated moderate policy readiness (60%), overall implementation fidelity remained low, with a mean implementation score of 40%. Patients frequently reported receiving nutrition counselling; however, documentation of counseling within clinical records was limited. Healthcare providers demonstrated moderate knowledge of nutrition recommendations, but implementation practices were comparatively weaker, with training deficiencies and limited educational resources identified as major provider barriers. Patient awareness was positively associated with reported dietary practices, although elevated blood pressure and random blood sugar levels remained common. Cost and affordability (63.5%) and cultural food norms (19.7%) were the most frequently reported barriers to implementing recommended dietary practices. The combined application of the SEM, RE-AIM, and KTA frameworks identified implementation gaps across organizational, provider, community, and policy levels. A substantial policy-to-practice gap exists in the implementation of nutrition guidelines for diabetes and hypertension in Region 3, Guyana. Strengthening provider capacity, implementation monitoring, clinical documentation and culturally responsive, affordable nutrition interventions are essential to improve implementation fidelity, support knowledge translation and enhance the sustainability of nutrition services within primary healthcare.*

Keywords *Diabetes Mellitus, Guyana, Hypertension, Implementation Fidelity, Implementation Science, Knowledge-to-Action (KTA), Mixed-Methods, Nutrition Guidelines, Policy-to-Practice Gap, RE-AIM, Social Ecological Model (SEM).*

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Introduction

Diabetes mellitus and hypertension are major contributors to the global burden of non-communicable diseases (NCDs), causing substantial morbidity, disability and premature mortality. The burden is particularly pronounced in low- and middle-income countries (LMICs), where health-system constraints, socioeconomic inequalities and limited resources can weaken prevention and long-term disease management [1-4]. Both conditions increase the risk of cardiovascular disease, stroke and chronic kidney disease, making effective lifestyle and clinical management a public-health priority.

Nutrition is central to the prevention and management of diabetes and hypertension. Evidence-based recommendations, including national Food-Based Dietary Guidelines (FBDGs), the Dietary Approaches to Stop Hypertension (DASH) dietary pattern and clinical nutrition guidance, support healthier food choices, blood-pressure management and glycaemic control. However, the existence of evidence-based guidance does not ensure consistent implementation. Across resource-constrained settings, translation into routine care may be limited by insufficient provider training, inadequate educational materials, inconsistent counselling and documentation, competing clinical priorities, and weak monitoring and evaluation systems [3, 4].

The Caribbean carries a substantial NCD burden, with diabetes and hypertension contributing importantly to premature morbidity and mortality [5]. Dietary transitions, dependence on imported and ultra-processed foods, the cost of healthier diets and culturally embedded food practices can make recommended dietary changes difficult to sustain [5, 6]. Regional initiatives, including the Port of Spain Declaration and the Pan American Health Organization HEARTS initiative, have therefore emphasized integrated primary care, cardiovascular risk management and healthier lifestyles; nevertheless, consistent implementation across Caribbean health systems remains challenging [7].

Guyana has developed national FBDGs and has promoted evidence-based approaches for NCD prevention and management, including DASH principles and WHO HEARTS [6, 7]. The revised FBDGs and implementation strategy provide an important policy foundation, but monitoring of implementation and long-term outcomes has remained limited [6]. Consequently, a policy-to-practice gap may occur when guidance is available but is not consistently embedded in routine counselling, documentation, monitoring and patient support. Published evidence examining this implementation process in Guyana, particularly across different levels of the health system, remains limited. This evidence gap is important because policy evaluation based only on the presence of guidelines or dissemination activities cannot determine whether patients are reached, whether providers adopt recommendations, whether counselling is delivered consistently, or whether implementation is maintained over time. Direct assessment of routine practice is therefore needed to distinguish policy readiness from implementation fidelity.

Implementation science provides useful approaches for examining this gap. The Social Ecological Model (SEM) identifies interacting influences at individual, interpersonal, organizational, community and policy levels [8]. RE-AIM assesses Reach, Effectiveness, Adoption, Implementation and Maintenance, enabling evaluation of both uptake and sustainability [9]. The Knowledge-to-Action (KTA) framework focuses on the processes required to move evidence into practice, including adaptation, implementation, monitoring, evaluation and sustainability [10, 11]. Used together, these frameworks permit assessment of contextual determinants, implementation performance and knowledge translation across the policy-to-practice pathway.

This study therefore assessed the implementation of nutrition guidelines for diabetes and hypertension across selected public health facilities in Region 3, Guyana, using a convergent mixed-methods design informed by SEM, RE-AIM and KTA. It examined facility readiness and implementation fidelity, provider knowledge and practice, patient awareness and reported dietary practices, clinical indicators, and multilevel barriers to implementation. By integrating quantitative and qualitative evidence, the study sought to identify where implementation weakened and to generate contextually relevant recommendations for strengthening nutrition services and implementation monitoring in Guyana.

Materials and Methods

Study Design and Setting

The researcher carried out a convergent mixed-methods implementation research study to assess the implementation of nutritional guidelines for diabetes and hypertension in Region 3, Guyana. The quantitative and qualitative parts were conducted simultaneously and integrated during the analysis phase to provide a comprehensive evaluation of implementation fidelity and contextual factors influencing policy implementation. The mixed-methods approach allowed the triangulation of the findings from different data sources and thus improved the analysis of implementation outcomes. The study was conducted in four public health facilities within Region 3: Goed Intent Health Centre (GIHC), Parfaite Harmonie Health Centre (PHHC), Leonora Cottage Hospital (LCH) and West Demerara Regional Hospital (WDRH). These facilities provide primary and secondary healthcare services and routinely manage patients with diabetes and hypertension.

Implementation Frameworks

The study was informed by three complementary implementation science frameworks. The Social Ecological Model (SEM) guided the examination of implementation determinants operating at the individual, interpersonal, organizational, community and policy levels. The Reach, Adoption, Effectiveness, Implementation and Maintenance (RE-AIM) framework was used to evaluate implementation across five implementation dimensions: including Programme reach, effectiveness, organizational adoption, implementation fidelity and maintenance. The Knowledge-to-Action (KTA) framework informed the assessment of knowledge translation processes, including adaptation of evidence, implementation, monitoring, and sustainability of nutrition guidelines within routine healthcare practice.

Population and Sampling

The study population comprised patients, healthcare providers, policymakers and community members. The quantitative component included a retrospective review of 2,745 patient records obtained from the four participating facilities. After data cleaning, 2,737 records containing valid blood pressure measurements and 2,055 records containing valid random blood sugar measurements were retained for analysis. Seventeen (17) healthcare practitioners, including physicians, nurses, nutrition specialists and multidisciplinary healthcare professionals engaged in the care and management of diabetes and hypertension, completed provider surveys. The qualitative component included semi-structured interviews with Ministry of Health officials and Programme managers responsible for implementing nutrition policy, eight focus group discussions with patients and community members and two community outreach activities to explore cultural, behavioral and socioeconomic factors influencing dietary

practices and implementation of nutrition recommendations.

Inclusion and Exclusion Criteria

Eligible subjects were ≥18y of age and had a confirmed diagnosis of hypertension, diabetes mellitus, or both. Healthcare practitioners directly involved in the clinical management of these conditions, including the provision of nutrition counselling and related patient care, were invited to participate. Policymakers responsible for the formulation, coordination or implementation of nutrition policies and Programme were eligible to participate.

Patient records were excluded for incomplete identifiers, implausible clinical measurements, or any other issue related to data integrity that could affect the robustness of the analysis. After data cleaning, eight implausible blood pressure values and one implausible random blood sugar value were excluded. Records without an RBS measurement were treated as missing rather than excluded from the overall dataset. For the qualitative component, participants who did not give informed consent for interviews or focus group discussions were excluded. In a similar way, participants with major co-morbidities not related to diabetes or hypertension were excluded as appropriate.

Data Collection and Study Variables

Data Collection

Data was collected using multiple complementary methods.

Facility Audit

A standardized facility audit instrument was used to assess implementation fidelity. The instrument comprised three domains: policy readiness, facility implementation, and general implementation. Policy readiness was evaluated based on the availability of nutrition policy documents, the Food-Based Dietary Guidelines (FBDGs), Dietary Approaches to Stop Hypertension (DASH) recommendations, World Health Organization (WHO) HEARTS materials, patient education resources, and supporting implementation documents. Facility implementation assessed the availability and documentation of nutrition counselling services, counselling resources, staff training, implementation protocols, and oversight mechanisms. General implementation examined the integration of nutrition counselling into routine clinical practice, monitoring and reporting systems, and mechanisms to support sustainability. An overall implementation fidelity score was derived using predefined audit criteria by averaging the policy readiness and facility implementation scores. The resulting implementation fidelity scores are presented in the Results section.

Patient Record Review

A systematic data extraction form was used to extract demographic and clinical data from the patient records. Variables included diagnosis, blood pressure measurements, random blood glucose, nutritional counselling, and other clinical markers relevant to management of diabetes and hypertension.

Healthcare Provider Survey

Healthcare practitioners completed standardized questionnaires on their knowledge of nutrition guidelines, current practices, perceived barriers to implementation, previous nutrition training and availability of educational resources.

Patient Survey

Participants completed interviewer-administered questionnaires to assess their knowledge of Food-Based Dietary Guidelines, Dietary recommendations for DASH, WHO HEARTS recommendations on salt and sugar reduction, receipt of nutritional counselling and self-reported eating habits.

Interviews, Focus Groups and Community Outreach

Semi-structured interviews with policymakers explored policy implementation processes, organizational challenges, and health system barriers. Eight focus group discussions and two community outreach activities explored community perceptions of healthy eating, cultural food practices, affordability of healthy diets, and barriers to adopting nutrition recommendations.

Study Variables

Primary implementation outcomes included: policy readiness, implementation fidelity, provider knowledge, provider practice, patient awareness and reported dietary practices. Clinical outcome variables included elevated blood pressure, defined as ≥140/90 mmHg, elevated random blood sugar, defined as ≥200 mg/dL, and missing random blood sugar measurements. Independent variables included age, sex, health facility, diagnosis, provider knowledge, patient awareness, and implementation indicators.

Statistical Analysis

IBM SPSS Statistics for Windows, Version 29.0 (IBM Corp., Armonk, NY, USA) was used to analyze the quantitative data. Summary statistics, including frequencies, percentages, means and standard deviations, were generated to describe the study variables. Chi-square tests were performed to examine differences among health facilities in patient awareness, dietary practices, documentation practices, and clinical outcomes. To determine associations between provider knowledge and implementation practice ($\rho = 0.78$, $p < 0.001$) and between patient awareness and reported dietary practices ($\rho = 0.707$, $p < 0.001$), Spearman's rank correlation coefficient was used. The researchers conducted multivariable logistic regression analyses to identify factors associated with high patient awareness, favorable dietary practices, elevated blood pressure, elevated random blood sugar and missing random blood sugar measurements. Odds ratios (ORs) with 95% confidence intervals (CIs) were reported, and statistical significance was established at $p < 0.05$.

Trustworthiness and Rigour

Qualitative findings were further corroborated by methodological triangulation (interviews, focus group discussions, community outreach activities, provider surveys and patient record analysis). Reliability was ensured by maintaining an audit trail of the selections made during data collection and analysis. Reflexive journaling and regular methodological conversations within the research team to minimize researcher bias strengthened the reliability of the findings. Transferability was enhanced through comprehensive descriptions of the study setting, participant characteristics and implementation context that would allow readers to assess the relevance of the findings to similar low- and middle-income healthcare contexts.

Results

Implementation Readiness and Policy-to-Practice Gap (KTA Framework)

All four participating health facilities demonstrated similar implementation fidelity. Each facility achieved a policy readiness score of 60% and a facility implementation score of 20%, resulting in an overall implementation fidelity score of 40%. Although nutrition policies and guidelines were available across all facilities, the low implementation scores indicate that these policies had not been consistently translated into routine clinical practice. Detailed facility-level implementation scores are presented in Table 1.

https://doi.org/10.21522/TIJAR.2014.13.04.Art016

Table 1. Facility Implementation Scoring Profile

Facility	Policy Readiness %	Facility Audit %	Overall Implementation %
GIHC	60.0	20.0	40.0
WDRH	60.0	20.0	40.0
PHHC	60.0	20.0	40.0
LCH	60.0	20.0	40.0

Facility assessments demonstrated similar implementation profiles across all four participating health facilities (Table 1). Each facility recorded a policy readiness score of 60.0%, a facility audit score of 20.0%, and an overall implementation score of 40.0%. Although nutrition policy documents, including the Food-Based Dietary Guidelines (FBDGs) and the WHO HEARTS guidance, were available across all facilities, implementation at the operational level remained limited. Deficiencies were observed in documentation systems, patient education resources, structured nutrition counselling tools and routine implementation processes.

Provider Adoption and Implementation (RE-AIM Framework)

Table 2. Provider Knowledge and Practice Profile

Facility	Provider n	Mean Knowledge %	Mean Practice %	Main Provider Barrier
GIHC	5	48.0	33.8	Training gap
WDRH	6	60.0	41.7	Materials gap
PHHC	4	45.0	46.9	Materials gap
LCH	2	60.0	50.0	Materials gap

Seventeen healthcare providers participated in the provider assessment. Mean provider knowledge scores ranged from 45.0% to 60.0% and mean implementation practice scores ranged from 33.8% to 50.0% across participating facilities (Table 2). The major implementation barrier at Goed Intent Health Centre (GIHC) was training deficiencies, whereas the main barriers at West Demerara Regional Hospital (WDRH), Parfaite Harmonie Health Centre (PHHC) and Leonora Cottage Hospital (LCH) were inadequate educational materials.

No statistically significant differences were observed among facilities in provider knowledge ($p = 0.874$) or implementation practice ($p = 0.748$). However, provider knowledge was strongly positively correlated with implementation practice (Spearman's $\rho = 0.780$, $p < 0.001$). In other words, the higher the knowledge score, the better the implementation practice.

These findings suggest moderate adoption of nutrition guidelines by healthcare providers, although consistent implementation remained limited across the participating facilities.

Patient Reach, Awareness and Adoption (RE-AIM Framework)

Table 3. Reported Dietary Practice and Patient Awareness

Facility	FBDG Aware %	DASH Aware %	High Awareness %	Low-salt Practice %	Low-sugar Practice %	High Practice %
GIHC	51.7	16.9	—	47.4	39.6	—
WDRH	75.6	48.2	52.2	—	—	—
PHHC	—	—	28.2	—	—	70.9
LCH	—	—	—	85.2	70.9	98.2

Patient awareness of nutrition recommendations varied significantly across the participating facilities (Table 3). Awareness of the Food-Based Dietary Guidelines (FBDGs) ranged from 51.7% to 75.6%, whereas awareness of the DASH dietary recommendations ranged from 16.9% to 48.2%. Overall high awareness varied from 28.2% at Parfaite Harmonie Health Centre (PHHC) to 52.2% at West Demerara Regional Hospital (WDRH).

Reported dietary practices also differed across facilities. High dietary practice was reported by 70.9% of the participants at Goed Intent Health Centre (GIHC) and 98.2% at Leonora Cottage Hospital (LCH). LCH had the lowest awareness of DASH dietary recommendations (16.9%) but had the highest percentage of participants reporting favorable dietary practices (98.2%).

There were significant differences between facilities for patient awareness ($\chi2 = 87.48$, $df = 3$, $p < 0.001$; Cramer's $V = 0.179$) and reported dietary practice ($\chi2 = 229.65$, $df = 3$, $p < 0.001$; Cramer's $V = 0.289$). Furthermore, a significant positive correlation was observed between patients' awareness and reported dietary practices (Spearman's $\rho = 0.707$, $p < 0.001$); suggesting that patients with higher awareness were more likely to report adherence to the recommended dietary practices.

Overall, the Programme reach and adoption varied across facilities, and increased patient knowledge appears to be related to increased self-reported adherence to the recommended dietary practices.

Table 4. Factors Associated with High Reported Dietary Practice: Multivariable Logistic Regression Analysis. Adjusted Model for High Reported Dietary Practice

Predictor	Adjusted OR (95% CI)	p value
Age	0.99 (0.98–1.00)	0.170
Facility: LCH vs GIHC	145.53 (64.88–326.43)	<0.001
Facility: PHHC vs GIHC	3.40 (2.33–4.94)	<0.001
Facility: WDRH vs GIHC	10.12 (6.85–14.95)	<0.001
Patient awareness %	1.11 (1.10–1.12)	<0.001
Barrier: Culture/Food norms vs Availability/Access	0.54 (0.29–0.99)	0.047
Barrier: Lack of knowledge vs Availability/Access	4.56 (2.21–9.42)	<0.001

Multivariable logistic regression identified several factors independently associated with high reported dietary practice (Table 4). Patient awareness was a significant predictor of favorable dietary practice (adjusted OR = 1.11; 95% CI: 1.10–1.12; $p < 0.001$). Compared with participants attending Goed Intent Health Centre (GIHC), those receiving care at Leonora

Cottage Hospital (LCH) (adjusted OR = 145.53; 95% CI: 64.88–326.43; p < 0.001), West Demerara Regional Hospital (WDRH) (adjusted OR = 10.12; 95% CI: 6.85–14.95; p < 0.001), and Parfaite Harmonie Health Centre (PHHC) (adjusted OR = 3.40; 95% CI: 2.33–4.94; p < 0.001) had significantly greater odds of reporting favorable dietary practices.

Participants identifying cultural food norms as their principal barrier had significantly lower odds of reporting high dietary practice (adjusted OR = 0.54; 95% CI: 0.29–0.99; p = 0.047), whereas those reporting lack of knowledge as the primary barrier had significantly higher odds of reporting favorable dietary practices (adjusted OR = 4.56; 95% CI: 2.21–9.42; p < 0.001). Age was not significantly associated with reported dietary practice (adjusted OR = 0.99; 95% CI: 0.98–1.00; p = 0.170). The model demonstrated good explanatory ability, accounting for approximately 40.6% of the variation in reported dietary practice (Pseudo $R^2 = 0.406$).

Clinical Indicators and Implementation Performance

Table 5. Facility-Level Clinical Indicators and Implementation Scores

Facility	BP Analysis n	BP ≥ 140/90%	RBS Analysis n	RBS ≥ 200%	RBS Missing %	Implementation %
GIHC	529	66.4	396	42.9	25.3	40.0
WDRH	1257	56.7	941	37.4	25.6	40.0
PHHC	500	66.2	305	30.2	39.0	40.0
LCH	451	59.0	413	32.9	8.4	40.0

***Note**: BP = blood pressure; RBS = random blood sugar; GIHC = Goed Intent Health Centre; WDRH = West Demerara Regional Hospital; PHHC = Parfaite Harmonie Health Centre; LCH = Leonora Cottage Hospital. Elevated BP was defined as ≥140/90 mmHg; elevated RBS was defined as ≥200 mg/dL among records with valid measurements. RBS missing (%) represents the proportion of patient records without a recorded RBS measurement.*

As shown in Table 5, among the n = 2,737 patient records with valid blood pressure measurements, the prevalence of elevated blood pressure (≥140/90 mmHg) ranged from 56.7% at West Demerara Regional Hospital (WDRH) to 66.4% at Goed Intent Health Centre (GIHC). Among the 2,055 records with valid random blood sugar measurements, the prevalence of elevated random blood sugar (≥200 mg/dL) ranged from 30.2% at Parfaite Harmonie Health Centre (PHHC) to 42.9% at GIHC. The proportion of missing random blood sugar results varied significantly across facilities, ranging from 8.4% at Leonora Cottage Hospital (LCH) to 39.0% at PHHC. Despite the differences in clinical indicators, the overall implementation score was still 40.0% in all of the facilities that participated.

Statistically significant differences were observed among facilities for elevated blood pressure ($\chi^2 = 22.32$, df = 3, p < 0.001; Cramer's V = 0.090), elevated random blood sugar ($\chi^2 = 14.95$, df = 3, p = 0.002; Cramer's V = 0.085) and missing random blood sugar measurements ($\chi^2 = 118.12$, df = 3, p < 0.001; Cramer's V = 0.207).

Multilevel Barriers to Nutrition Guideline Implementation (SEM Framework)

https://doi.org/10.21522/TIJAR.2014.13.04.Art016

Table 6. Patient-Level Barriers to Nutrition Guideline Implementation

Barrier Category	Patient n	Patient %
Cost/Affordability	1,743	63.5
Culture/Food norms	540	19.7
Lack of knowledge	180	6.6
Time/Workload	161	5.9
Availability/Access	121	4.4

The most frequent barriers to adopting the recommended dietary practices were financial constraints and affordability, reported by 63.5% of the respondents (Table 6). The second most common barrier was cultural diet norms (19.7%), followed by lack of knowledge (6.6%), lack of time or workload (5.9%) and limited food availability or access (4.4%).

There was a significant association between the classification of barriers and patient awareness ($\chi 2 = 39.81$, $df = 4$, $p < 0.001$; Cramer's $V = 0.120$) and documented dietary behavior ($\chi 2 = 20.23$, $df = 4$, $p < 0.001$; Cramer's $V = 0.086$). The quantitative data were supplemented by qualitative insights from focus group discussions and community outreach activities, which illuminated the primary themes influencing the implementation of nutrition guidelines: cultural and household food practices, communication and outreach strategies, understanding of disease management, awareness of healthy diets, and cost.

Integrated Implementation Science Assessment

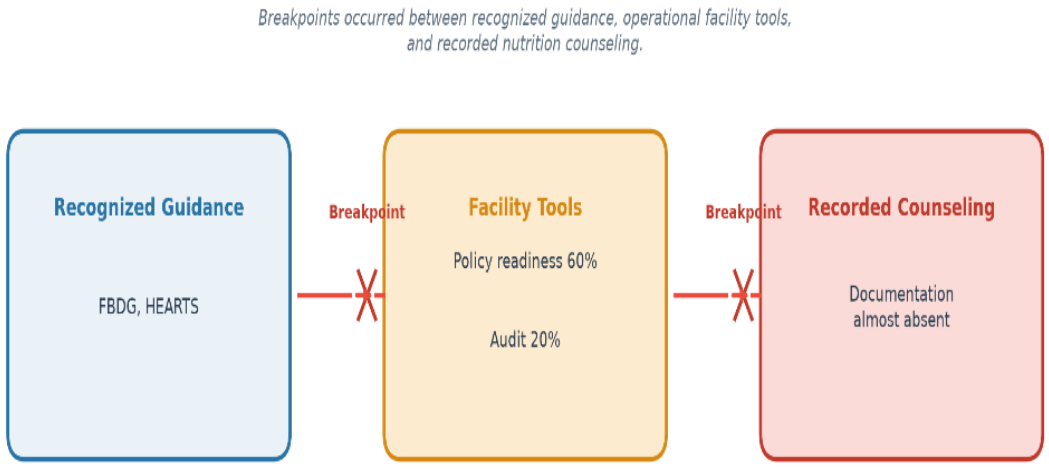


Figure 1. Policy-to-Practice Pathway for Nutrition Guideline Implementation

Figure 1 illustrates the progression of nutrition guidelines from national policy development to routine implementation within participating healthcare facilities. Although evidence-based guidance, including the Food-Based Dietary Guidelines (FBDGs), Dietary Approaches to Stop Hypertension (DASH) recommendations and the WHO HEARTS framework, was available across the health system, discontinuities were observed between policy availability and routine implementation. These gaps were evident in the availability of implementation resources, documentation systems, structured nutrition counselling, and monitoring processes, highlighting measurable breakpoints along the policy-to-practice pathway.

https://doi.org/10.21522/TIJAR.2014.13.04.Art016

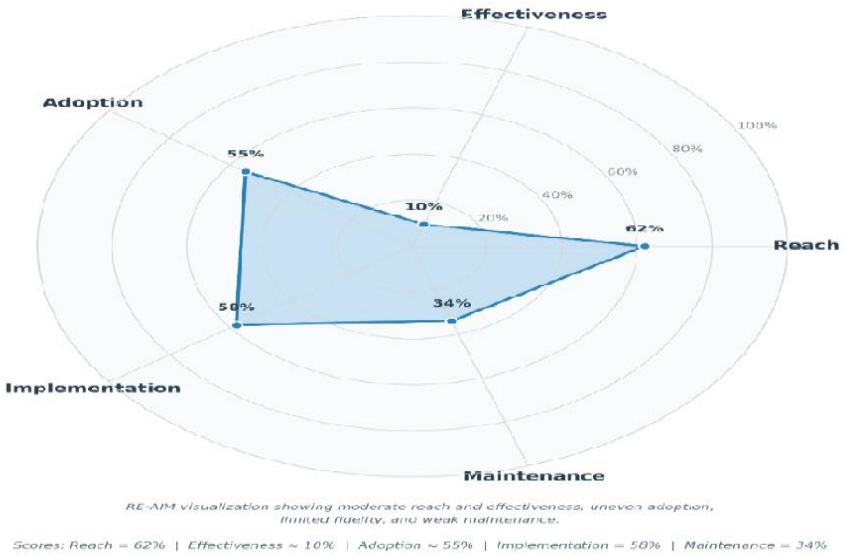


Figure 2. RE-AIM Assessment of Nutrition Guideline Implementation

As illustrated in Figure 2, the RE-AIM evaluation revealed moderate levels of program efficacy across the various areas of implementation. Program reach was estimated at 62%, adoption at 55%, and implementation at 58%. Maintenance (34%) and effectiveness (approximately 10%) were much lower. These results reveal inconsistencies across the five RE-AIM dimensions and indicate that long-term sustainability and program efficacy were less favorable than initial program reach and adoption.



Figure 3. Application of the Knowledge-to-Action (KTA) Framework

Figure 3 illustrates the application of the Knowledge-to-Action (KTA) framework to nutrition guideline implementation, across the participating health facilities. Performance was strongest during the knowledge creation phase, as is evidenced by the availability of the Food-Based Dietary Guidelines (FBDGs), Dietary Approaches to Stop Hypertension (DASH) recommendations and the WHO HEARTS framework. In contrast, comparatively lower

performance was observed during the action cycle, particularly in knowledge adaptation, implementation, monitoring, evaluation, feedback and sustainability. These findings highlight measurable gaps in the translation of evidence-based nutrition guidance into routine clinical practice.

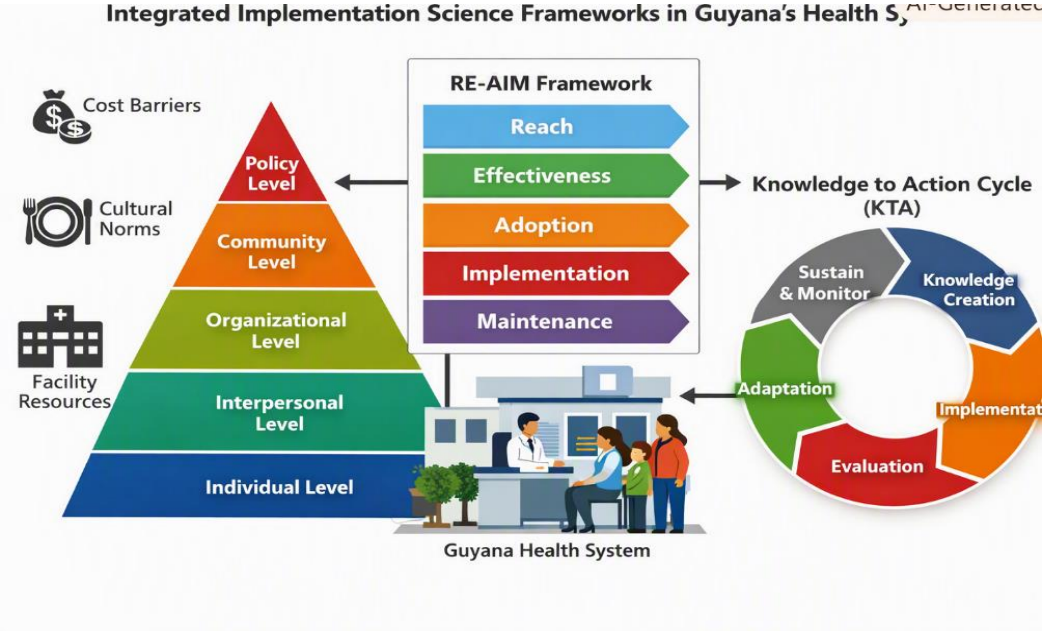


Figure 4. Integrated SEM–RE-AIM–KTA Framework for Nutrition Guideline Implementation

Figure 4 presents an integrated implementation science framework synthesized from the study findings. The framework illustrates how the Social Ecological Model (SEM), the Reach, Effectiveness, Adoption, Implementation and Maintenance (RE-AIM) framework, and the Knowledge-to-Action (KTA) framework complement one another in evaluating the implementation of nutrition guidelines for diabetes and hypertension. It explores how policy-related mandates, organizational implementation approaches, healthcare provider acceptance, patient outreach and engagement and complex contextual barriers influence the integration of evidence-based nutrition guidelines into routine clinical practice in Region 3, Guyana.

Discussion

This mixed-methods research revealed a significant gap between policy and practice in implementing nutritional guidelines for diabetes and hypertension across four public health institutions in Region 3 of Guyana. Evidence-based nutritional guidelines were in place, but policy readiness was average, and the overall implementation rate was 40%. Providers' knowledge was moderate but not consistently translated into practice. However, patient awareness varied across facilities and was associated with reported dietary behavior; hence, substantial proportions of patients had elevated blood pressure and random blood glucose levels. These clinical observations should not be viewed as direct evidence of implementation effectiveness, but rather as the ongoing clinical challenges to successful disease management in the cohort under study. The quantitative and qualitative findings further indicated that organizational capacity, documentation systems, provider resources, affordability, household practices and cultural food norms influenced the translation of nutritional guidance into routine care. These central findings, therefore, are not due to a lack of nutritional policy, but to an incomplete translation of existing policies and guidelines into sustained routine practice. The RE-AIM

assessment reinforces this interpretation by showing that the reach (62%), adoption (55%) and implementation (58%) were moderate, whereas maintenance (34%) and effectiveness (approximately 10%) were substantially weaker. This pattern suggests that the initial dissemination and uptake were more advanced than the mechanisms needed to sustain implementation and achieve a measurable clinical impact. These findings therefore support conceptualizing implementation as a continuum, in which policy availability and the initial adoption represent only part of the pathway towards sustained delivery and improved health outcomes.

Policy Readiness versus Implementation Fidelity: A Knowledge-to-Action Perspective

All participating facilities recorded policy readiness of 60% but facility implementation of only 20%, producing an overall implementation score of 40%. This discrepancy indicates that policy availability and recognition did not correspond to equivalent operationalization within routine services. Guyana's FBDGs, DASH recommendations and WHO HEARTS provide an evidence base for nutrition-related NCD care, but implementation requires additional mechanisms that support local adaptation, counselling delivery, documentation, monitoring and feedback [12].

The KTA framework helps locate this breakpoint. Knowledge creation appeared comparatively well established through the availability of recognized guidance, whereas weaknesses were more apparent within the action cycle. In particular, the findings point to gaps in adaptation to local service conditions, operational implementation, documentation, monitoring, evaluation and sustainability [13, 14]. The policy-to-practice gap therefore appears to emerge mainly after policy adoption, when guidance must be incorporated into everyday clinical workflows. This distinction has practical importance for policy evaluation. Counting policies, guidelines or training events can overestimate implementation if routine service processes are not assessed. Implementation indicators should therefore capture whether counselling is delivered, documented, supported with appropriate resources and reviewed through ongoing quality-improvement mechanisms [15]. Facility-level audit findings also showed that the same broad implementation weaknesses were present across settings despite differences in facility size and service delivery. This uniformity may indicate system-wide limitations in the structures supporting nutrition care rather than isolated shortcomings at a single facility. It also suggests that national or regional implementation standards may be useful for establishing minimum expectations for counselling, documentation, training, supervision and monitoring. The discrepancy between patient reports of counselling and limited clinical documentation illustrates this challenge. Undocumented counselling cannot be assumed to represent absence of care; however, inconsistent documentation weakens continuity, quality monitoring and the ability to determine whether implementation is occurring as intended.

Provider Knowledge, Adoption and the Knowledge-Practice Gap

Provider knowledge scores ranged from 45% to 60%, while practice scores ranged from 33.8% to 50.0%. Although provider knowledge and practice were positively correlated, the small provider sample (n = 17) requires cautious interpretation. The findings nevertheless suggest that knowledge alone is insufficient to ensure consistent nutrition counselling. Providers identified training gaps and limited educational materials as important constraints, with the predominant barrier differing by facility. At GIHC, training gaps were the most prominent barrier, whereas limited materials were reported more frequently at WDRH, PHHC and LCH. These differences

are important because they demonstrate that similar implementation scores can arise from different underlying constraints. These results are consistent with implementation evidence showing that evidence-based recommendations are more likely to become routine when provider capability is supported by appropriate resources, workflow integration, supervision and organizational reinforcement [4, 16, 17].

From a RE-AIM perspective, moderate provider knowledge suggests partial adoption, whereas lower practice scores indicate weaker implementation. This distinction is important because dissemination and professional awareness do not necessarily produce high implementation fidelity. Facility-specific barriers also suggest that a uniform intervention may be less effective than strategies tailored to local organizational needs. Refresher training, practical counselling tools, standardized documentation and supportive supervision may therefore be more useful when implemented as part of a coordinated facility-level strategy rather than as isolated educational activities.

Patient Reach, Awareness and Reported Dietary Practices

Patient awareness varied substantially across facilities. FBDG awareness ranged from 51.7% to 75.6%, while DASH awareness ranged from 16.9% to 48.2%; high overall awareness ranged from 28.2% to 52.2%. Reported low-salt and low-sugar practices also varied, demonstrating that reach and behavioural uptake were not uniform across facilities. Awareness of the FBDGs was consistently higher than awareness of DASH, while higher awareness was associated with more favourable reported dietary practice. In the adjusted model, patient awareness remained independently associated with high reported dietary practice, supporting the importance of nutrition education. However, the very large facility effect observed for LCH and other facility differences should not be interpreted as causal rankings of facility quality. They may reflect differences in patient composition, counselling exposure, outcome prevalence or other measured and unmeasured contextual characteristics.

Reported dietary practice also requires cautious interpretation. The composite measure reflected selected behaviours, particularly low-salt and low-sugar practices, rather than comprehensive adherence to the full FBDG or DASH dietary pattern. Recall and social-desirability bias may therefore have contributed to the relatively favourable practice classifications. The findings support continued patient education [18], but education should emphasize practical application of dietary recommendations using affordable and culturally acceptable foods, barrier assessment and realistic goal setting [19, 20].

Clinical Indicators and the Policy-to-Practice Gap

Elevated blood pressure and random blood sugar remained common despite comparatively favourable reported dietary practices. Elevated blood pressure affected more than half of patients at each facility, ranging from 56.7% to 66.4%, while elevated random blood sugar ranged from 30.2% to 42.9% among records with available measurements. These findings highlight the distinction between implementation-related behavioural indicators and clinical control. Facility differences in these indicators were statistically significant but had small effect sizes, suggesting that facility context explained only a limited proportion of clinical variation. Clinical control is influenced by multiple factors beyond dietary awareness, including medication adherence, disease duration and severity, comorbidities, healthcare access and socioeconomic conditions. The cross-sectional design also prevents determination of whether reported dietary practices preceded the measured clinical outcomes. These findings therefore reinforce that awareness and self-reported behaviour are important implementation outcomes but should

not be treated as substitutes for objective clinical improvement.

Missing random blood sugar measurements also varied across facilities. This is relevant not only as a data-quality issue but as a potential indicator of differences in monitoring processes. Strengthening implementation should therefore include reliable clinical measurement and documentation alongside counselling and patient education.

Multilevel Barriers: A Social Ecological Perspective

Cost and affordability were the dominant patient-level barriers (63.5%), followed by cultural food norms (19.7%). Lack of knowledge (6.6%), time or workload constraints (5.9%) and availability or access (4.4%) were less frequently reported but remained relevant. Barrier category was significantly associated with both patient awareness and reported dietary behaviour, although effect sizes were small, indicating that these relationships should be interpreted as part of a wider set of influences rather than as dominant causal explanations. Qualitative findings similarly emphasized household food practices, information pathways, disease understanding and the practical affordability of healthier choices. The SEM demonstrates why interventions directed only at individual knowledge are unlikely to be sufficient. Patients may understand dietary recommendations but remain constrained by household preferences, food prices, cultural expectations and access to appropriate foods [21-25].

Organizational barriers interacted with these patient-level constraints. Limited educational materials, training gaps, inconsistent documentation and variable counselling practices reduced the capacity of facilities to support sustained behaviour change. Implementation strategies should therefore operate across levels: strengthening provider and organizational capacity within facilities while also addressing community communication, culturally appropriate dietary adaptation and affordability.

Integrated Interpretation Through SEM, RE-AIM and KTA

The three frameworks provided complementary rather than competing explanations. KTA identified the weakening of translation after policy adoption; RE-AIM demonstrated moderate reach and adoption but weaker implementation, effectiveness and maintenance; and SEM located the determinants of these outcomes across individual, interpersonal, organizational, community and policy levels. Their integration provides a coherent explanation of why the presence of evidence-based guidance has not yet produced consistent routine implementation.

The framework synthesis also helps explain why apparently positive findings in one domain should not be interpreted in isolation. For example, moderate reach does not guarantee effectiveness, provider adoption does not guarantee consistent implementation, and the existence of national guidance does not guarantee maintenance. Similarly, patient knowledge may support healthier choices but cannot remove financial or cultural constraints. Considering these dimensions together avoids attributing implementation failure solely to patients or providers and instead identifies modifiable system-level conditions. This integrated interpretation is an important contribution of the study. It shifts attention from whether nutrition policies exist to whether the health system has the processes, resources and contextual supports needed to sustain them. In Region 3, strengthening implementation will require coordinated action across policy, facility, provider and community levels, with routine monitoring used to identify gaps and adapt strategies over time.

Implications for Policy and Practice

The findings indicate that strengthening nutrition services in Guyana requires greater emphasis on implementation systems, not only policy development. Facilities should introduce standardized, low-burden counselling and documentation tools, including brief nutrition-assessment prompts and structured fields for recording counselling topics, agreed dietary goals, referrals and follow-up plans. These tools should be integrated into existing workflows so that documentation supports continuity of care, implementation monitoring and quality improvement without creating unnecessary administrative burden.

Provider development should combine refresher education with practical counselling skills, culturally responsive communication, behaviour-change approaches and access to appropriate patient-education materials. Training should be reinforced through supportive supervision and periodic competency review so that knowledge is translated into observable routine practice. Facility managers should also ensure that counselling resources are consistently available at points of care and that responsibility for nutrition counselling and follow-up is clear within multidisciplinary teams. Because the dominant provider barriers differed across facilities, implementation support should be responsive to local needs while maintaining common minimum standards for counselling and documentation.

The predominance of affordability and cultural food norms also requires action beyond health facilities. Community-based nutrition initiatives and collaboration across health, agriculture, education and social-protection sectors should support access to affordable healthy foods and culturally appropriate dietary modification. Nutrition education should translate FBDG and DASH principles into realistic meals that reflect household resources and local food practices.

Finally, routine implementation monitoring should include facility fidelity indicators, provider competency, counselling documentation, patient-reported outcomes and relevant clinical measures. Monitoring should be designed as a feedback mechanism rather than solely as an accountability exercise. Regular review of facility-level indicators could help teams identify gaps, test corrective actions and determine whether improvements are maintained. Where feasible, implementation data should be linked with clinical indicators so that increases in counselling and documentation can be assessed alongside blood-pressure and glycemic outcomes. These data can support continuous quality improvement and allow managers to identify where implementation is weakening. Future research should use longitudinal designs to determine whether improvements in implementation fidelity are sustained and whether they translate into better behavioural and clinical outcomes, and should examine implementation across other regions of Guyana.

Strengths and Limitations

A major strength of this study was its integration of implementation science frameworks with mixed-methods evidence. The combined use of SEM, RE-AIM and KTA enabled implementation to be examined across multiple ecological levels while also assessing implementation performance and knowledge translation. Triangulation of facility audits, provider assessments, 2,745 patient records, patient data and qualitative evidence from interviews, focus groups and community outreach provided a broad view of both measurable implementation outcomes and the context in which they occurred. Inclusion of four public facilities spanning different service-delivery settings also strengthened the relevance of the findings to Region 3.

Several limitations require consideration. The cross-sectional design precludes causal or temporal conclusions regarding

implementation, awareness, dietary behaviour and clinical outcomes. Some provider and patient measures were self-reported and may be affected by recall or social-desirability bias. The provider sample was small (n = 17), limiting statistical power and the generalizability of provider-level comparisons and correlations. Missing random blood sugar measurements varied across facilities and may have influenced glycaemic comparisons. Identical facility-audit scores may reflect shared implementation conditions but may also indicate limited sensitivity of the audit instrument to more subtle differences in implementation quality. Finally, the study involved four selected facilities in Region 3; findings should not automatically be generalized to all facilities or administrative regions in Guyana. Despite these limitations, the convergence of multiple data sources provides a robust basis for identifying priority implementation gaps. The qualitative component is particularly valuable because it helps explain why similar quantitative implementation scores may coexist with different provider and patient experiences across facilities. Nevertheless, the qualitative findings are context-specific and should be interpreted as explanatory evidence rather than population prevalence estimates.

Conclusion

A substantial policy-to-practice gap was identified in the implementation of nutrition guidelines for diabetes and hypertension across the participating facilities in Region 3, Guyana. Evidence-based guidance was available, but routine implementation was constrained by weak implementation fidelity, inconsistent documentation, provider resource and training limitations, and socioeconomic and cultural barriers.

The integrated SEM, RE-AIM and KTA analysis showed that successful implementation requires more than policy availability: it depends on effective knowledge translation, supportive organizational systems, practical provider capacity, culturally responsive patient support and sustained monitoring. Strengthening these components can improve the consistency and sustainability of nutrition services and provides a practical direction for health-system improvement in Guyana and comparable LMIC settings.

Conflict of Interest

The authors declare no conflicts of interest related to the design, conduct or reporting of this study.

Ethical Approval

Ethical approval for the study was obtained from Texila American University and the Institutional Review Board (IRB) of the Ministry of Health, Guyana (Approval Reference: 029/2026). The study was conducted in accordance with the principles of the Declaration of Helsinki (2013 revision). All participating healthcare providers and patients provided informed consent before inclusion in the study. Patient data were anonymized at the point of extraction to protect confidentiality and privacy.

Author's Contribution

Selese Melanee Shepherd-Holder: Conceptualization, Methodology, Investigation, Formal analysis, Writing—original draft. Michael Olabode Tomori: Supervision, Project administration, Writing—review and editing. Both authors reviewed and approved the final manuscript.

Data Availability

The datasets generated and analyzed during this study are not currently publicly available due to patient confidentiality. However, once permission is granted by the Guyana Ministry of Health, the corresponding author can make the data available.

Acknowledgements

The authors acknowledge the Guyana Ministry of Health and the Regional Health Department of Region Three for their administrative support and facilitation of the research. Appreciation is extended to the healthcare providers and staff of the Goed Intent Health Centre, Parfaite Harmonie Health Centre, Leonora Cottage Hospital and West Demerara Regional Hospital for their participation and cooperation. The authors also thank the patients and community members whose perspectives contributed to the study. The lead author appreciates the guidance and knowledge provided by the academic mentors and dissertation committee, which helped to advance the research conceptually and methodologically.

Funding

No external funding was received for the study. The research was entirely funded by the principal author, Selese Melanee Shepherd-Holder.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art017

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Effect of Health Belief Model-Based Nutrition Education Intervention on Nutritional Status of Pregnant Women in Rural Western Ethiopia: A Cluster Randomized Controlled Trial, 2026

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Cite this article as: Koang Nyak Bol, Sebit Mustafa Sebit, Surender Reddy Pulluri. Effect of health belief model-based nutrition education intervention on nutritional status of pregnant women in rural Western Ethiopia: a cluster randomized controlled trial, 2026. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art017**

Received: 26.08.2026

Accepted: 09.10.2026

Published: 30.10.2026

Article Type: Original Research

Abstract *Maternal undernutrition affects 19.5% to 41.2% of pregnant women in Ethiopia, with limited progress from conventional programs. Despite the recognized benefits of theory-driven approaches, behavioral frameworks to guide maternal nutrition education interventions are not explored through interventional designs in severely affected rural pastoralist settings. This community-based, two-arm cluster-randomized controlled trial evaluated the effectiveness of a Health Belief Model-based nutrition education intervention in promoting nutritional status among 328 pregnant women (164 per arm) in rural Nuer Zone, Gambella Region, Western Ethiopia, from March to June 2026. A standard non-stretchable Middle-Upper Arm Circumference (MUAC) tape was used to assess nutritional status. Linear Mixed-Effects Models with Mediation analysis were employed to test intervention effects and pathways through Health Belief Model (HBM) constructs. At baseline, the prevalence of undernutrition (MUAC < 23 cm) was comparable between intervention and control groups (30.2% vs. 24.5%, respectively, p = 0.285), and mean MUAC values were similar (24.08 cm vs. 24.28 cm, p = 0.285). At endline, the intervention group showed a 1.334 cm increase in mean MUAC, compared with a 0.455 cm decline in controls (DiD = 1.789 cm, 95% CI: 1.485–2.093, p < 0.001). Likewise, undernutrition prevalence decreased from 30.2% to 5.6% in the intervention group, while it increased from 24.5% to 26.4% in controls, with changes in HBM constructs mediating 51.4% of the intervention effect. The HBM-based education intervention significantly improved nutritional status among pregnant women in rural western Ethiopia. Integrating theory-driven behaviour change approaches into Ethiopian maternal nutrition programs is recommended.*

Keywords *Cluster-Randomized Controlled Trial, Health Belief Model, Maternal Nutrition Education, MUAC, Nutritional Status, Rural Ethiopia.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art017

Introduction

Undernutrition denotes insufficient intake of energy and nutrients needed to maintain health [1]. It manifests in four broad forms: wasting, stunting, underweight, and micronutrient deficiencies [1]. Pregnant mothers are more vulnerable to undernutrition owing to the increasingly high energy and nutrient needs of pregnancy [2]. Maternal undernutrition causes an estimated 20 million low birth weights [3] and 800,000 neonatal deaths each year [4]. It is associated with child stunting and wasting [5, 6] and poor cognitive and mental development, leading to suboptimal educational performance, limited employment opportunities, and lower economic productivity [7]. Moreover, it is associated with an increased lifelong risk of chronic diseases, including hypertension and diabetes [7]. Globally, over one billion adolescent girls and women suffer from undernutrition [8]. In developing countries, the prevalence of undernutrition among pregnant women ranges from 13% to 38% [9]. Iron deficiency anemia is a major contributor to maternal mortality, and nearly 3.1 million children die annually from consequences related to pregnancy undernutrition in these countries [4]. Sub-Saharan Africa and South Asia are severely affected by maternal undernutrition due to chronic micronutrient deficiencies [9], accounting for approximately 68% of the world's underweight adolescent girls and women and 73% of low birth weight deliveries [8].

Factors influencing the nutrition of pregnant women comprise multifaceted sociocultural and economic factors, causing disparate variation in the burden of undernutrition across geographical regions and countries [10]. Ethiopia made considerable efforts to improve maternal and child nutrition over the past decades. It adopted its first stand-alone National Nutrition Program (2008–2015) focused on improving the nutrition of mothers and children through scaled-up nutrition-specific interventions [11]. Recognizing the need for multisector collaboration in promoting nutrition and attaining the Sustainable Development Goals (SDGs), Ethiopia developed its second National Nutrition Program in harmony with the country's Growth and Transformation Plan (GTP II: 2016–2020) to provide legal frameworks for mainstreaming nutrition into multisector strategies and programs, including the Nutrition-Sensitive Agriculture Strategy, National Food Security Strategy, National Health Sector Transformation Plan, National Food Fortification Program, and the National School Health and Nutrition Strategy [12]. The National Food and Nutrition Policy emphasized promoting access to diversified, nutritious foods for all citizens to break the vicious cycle of undernutrition and improve life expectancy [13]. Despite these efforts, the burden of undernutrition among Ethiopian pregnant women is high, varying from 19.5% to 41.2% [14], with rural areas heavily affected [15]. Systematic reviews showed that the pooled prevalence among pregnant women was 32% [16]. Similarly, studies revealed a high prevalence of inadequate dietary diversity practices (38.8% to 73.6%) among Ethiopian pregnant women [14, 17]. According to a case study review of implementation experience to improve maternal nutrition in Ethiopia, education and counseling provided through the routine health systems were ineffective in promoting nutrition behaviours [18].

Indeed, behavioral interventions are evaluated using theory in the context in which they occur to understand the drivers of behaviours and the process of change [19]. The Health Belief Model (HBM) is a social psychological theory that focuses on individuals' attitudes and beliefs to predict health behaviors [20]. According to this model, behavior change is driven by individuals' perceptions about health threats and their beliefs about benefits and barriers to undertaking prescribed health action [20].

HBM assumes that people are rational—they eliminate (reduce) risky health behavior when provided with adequate understanding of its consequences [20]. It conceptualizes that people are afraid of serious illnesses, and that adopting health-promoting behaviors reflects both a person's level of fear of perceived health threats and beliefs about the effectiveness of the recommended health behavior at an acceptable cost [20]. The model covers six cognitive constructs: perceived susceptibility to illness, perceived severity of illness and its consequences, perceived benefits of health behavior, perceived barriers to adopting a behavior, perceived self-efficacy, and cues to action [20]. The HBM has proven effective in improving nutrition behaviours across populations. According to a study in Gujarat State, India, nutrition education based on the Health Belief Model significantly improved the nutritional status of pregnant women [21]. Unlike broader social-ecological models, the HBM provides a structured framework for designing practical, individualized counselling strategies delivered through community health workers (Figure 1).

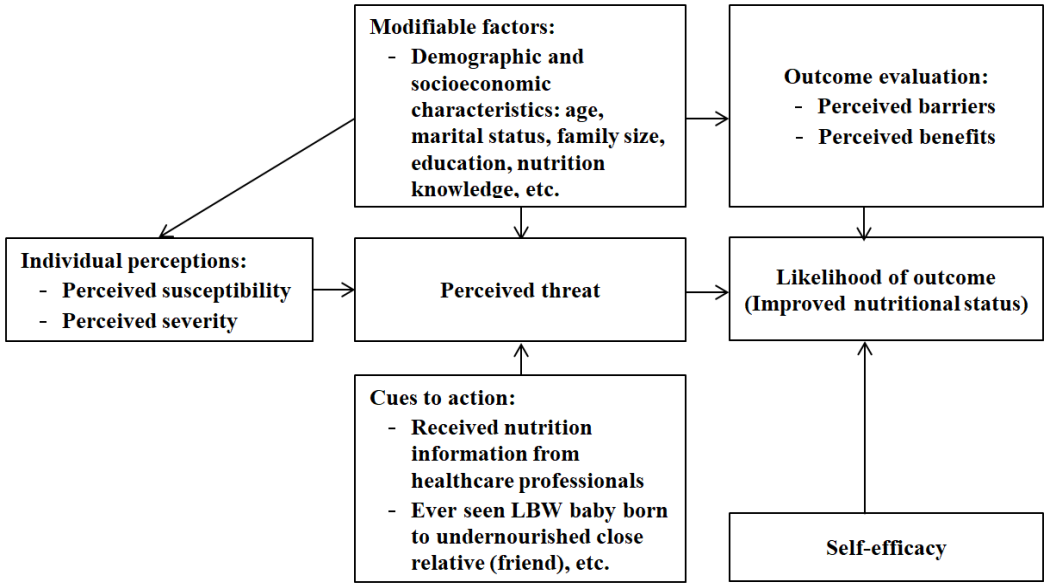


Figure 1. Theoretical Model for Promoting Nutrition of Pregnant Women Using the Health Belief Model [20]

Despite the recognized importance of theory-driven interventions, behavioural frameworks to guide maternal nutrition education in rural pastoralist settings of Ethiopia are not adequately explored through interventional designs. In addition, the existing nutrition programs in these settings lack rigorous evaluation. This trial aimed to evaluate the effectiveness of Health Belief Model-based nutrition education interventions in improving the nutritional status of pregnant women in rural western Ethiopia. The study will inform the design of contextually sensitive education programs to promote maternal nutrition in rural, low-resource settings.

Methods and Materials

Study Design and Setting

A community-based pretest-posttest cluster-randomized controlled trial was conducted to assess the effect of a nutrition education intervention based on the Health Belief Model on the nutritional status of pregnant women in Nuer Zone, Gambella Region, Western Ethiopia, from March to June 2026. The zone is a lowland rural setting (elevation 400–430 meters above sea level) where the population predominantly pursues an agro-pastoral livelihood, relying on mixed crop cultivation, livestock rearing, and fishing. It comprises five districts and 121 kebeles (the smallest

administrative units); one primary hospital, eight health centers, and 47 health posts. According to the 2026 projection, Nuer Zone has a total population of 206,598, of whom 53,922 are women of reproductive age, and 6,198 are pregnant women.

Participants Eligibility Criteria

The source population included all pregnant women residing in the Nuer zone, western Ethiopia. The study population was pregnant women in the selected districts. Women in their first or second trimester (confirmed gestational age ≤ 16 weeks) were eligible, thereby providing an adequate window to complete the intervention before delivery. Women of gestational age exceeding 16 weeks were excluded from the study.

Sample Size Determination

The sample size was calculated for the dietary diversity outcome using G*Power version 3.1.9.7 [22] for a two-sample t-test. At a 95% confidence level ($\alpha = 0.05$), power of 80%, effect size of 0.4, and an allocation ratio of 1:1, the sample size was 156. Considering the design effect of 2 and a 10% non-response rate, the sample size becomes 328 (164 participants per arm). The effect size was considered from a cluster-randomized trial conducted in the West Gojam zone of Ethiopia, which revealed a mean Dietary Diversity Score (DDS) of 5.4 ± 1.8 for the intervention group, in contrast to 4.5 ± 1.6 for the control group at the endline, resulting in a Cohen's d effect size of 0.4 [10]. The sample size was adequate for both the primary MUAC outcome and the secondary DDS outcome, with post-hoc power calculation confirming >99% power for MUAC and >90% power for DDS based on the observed effect sizes.

Sampling Procedures - Randomization

A multi-stage stratified sampling strategy was adopted. In the first stage, four of the five rural districts of Nuer Zone were selected using a pseudo-random number generator. In the second stage, these four districts (namely Lare, Jikaw, Makuey, and Wanthoa) were stratified by population density (high vs. low) and health facility accessibility (high vs. low). Within each stratum, districts were randomly assigned to intervention or control arms using a computer-generated random sequence. This stratification ensured balance in key district-level characteristics between arms. In the third stage, 22 kebeles (20% of kebeles) were randomly drawn from each selected district using computer-generated random numbers. A household screening was carried out by health extension workers in these kebeles to identify eligible pregnant women and establish a sampling frame. To minimize cross-contamination, we selected non-adjacent kebeles within each district, with a minimum distance of 5 km between intervention and control clusters. Additionally, health extension workers were instructed not to discuss the intervention content with women in control kebeles (clusters). Within each kebele, eligible women were recruited via systematic random sampling from the sampling frame, with the sampling interval (k) calculated as the total number of pregnant women in the kebele divided by the required sample quota.

Blinding

Complete blinding of participants and intervention facilitators to group allocation was not logistically feasible owing to the overt nature of the educational sessions. Nevertheless, both arms were uninformed about the specific study hypotheses and the primary endpoint to reduce performance bias. Control group participants were told that they would receive the educational materials upon completion of the endline survey, rather than being explicitly designated as a "control group", thereby minimizing resentment or compensatory behavioral changes. Data collectors responsible for outcome measurement were strictly blinded to group allocation throughout the study.

Theoretical Framework

The intervention was designed using the Health Belief Model (HBM) as its foundational behavioral underpinning. The HBM postulates that the likelihood of adopting a health-protective behavior is determined by an individual's perception of threat (susceptibility and severity) and their evaluation of the recommended action (benefits versus barriers), along with self-efficacy and cues to action. The educational content targeted six core HBM constructs: perceived susceptibility to pregnancy-related undernutrition, perceived severity of its consequences, perceived benefits of adequate nutrition, perceived barriers to optimal eating practices, confidence in one's ability to change (self-efficacy), and environmental prompts for action (cues to action). HBM was selected for this intervention because it explicitly addresses the cognitive and perceptual factors most relevant to dietary behavior in low-resource settings, particularly perceived barriers (e.g., food access, cost, cultural taboos) and perceived severity (awareness of health consequences). It was hypothesized that the intervention would exert its effect on MUAC by first modifying these six core constructs, and this mediational pathway was formally tested using mediation analysis.

Description of the Intervention

Participants in the intervention arm were provided with a nutrition education session once monthly over three consecutive months. All educational materials (facilitator manuals, pictorial leaflets, brochures, and counseling cards) were developed in alignment with the latest dietary and nutrition guidelines from the World Health Organization, the Food and Agriculture Organization, and Ethiopia's Federal Ministry of Health [23-25]. The curriculum covered: the physiological consequences of maternal undernutrition; increased energy and nutrient demands during gestation; the short- and long-term health, economic, and social repercussions of poor nutritional status for both the mother and offspring; the role of diverse, locally available, nutrient-dense foods in promoting adequate gestational weight gain and maintaining MUAC; culturally embedded food taboos and their harmful effects; proper food handling and hygiene; and the importance of adhering to iron–folic acid and iodized salt supplementation. Each monthly education session, lasting three hours, was delivered in the local Nuer language. Participatory adult-learning techniques, including moderated group discussions, brainstorming exercises, cooking demonstrations, and role-play scenarios, were employed to foster engagement and retention. The sessions were facilitated by four health professionals holding bachelor's degrees and two holding master's degrees, selected for their prior experience and fluency in the local dialect. They underwent a standardized five-day training workshop on the intervention protocol and facilitation methods. Additionally, community health extension workers, who received a one-day orientation, conducted biweekly home visits lasting 30-60 minutes to provide individualized nutrition counseling. During these visits, they helped women identify practical barriers to dietary improvement and reinforced problem-solving skills to strengthen self-efficacy. Endline data were gathered one month after the final group session to capture sustained changes in nutritional status. Women in the control group received routine antenatal care, which includes standard nutrition counseling on iron-folic acid supplementation and dietary diversity as per Ethiopia's national guidelines, but no structured, theory-based education sessions or home visits. They received full educational materials and were provided a condensed version of the education intervention after endline survey. Attendance was monitored at each group session, with a mean attendance rate of 89.7% (range: 78–95%) across the three sessions. Home visit

completion rates averaged 92.3% (range: 85–98%), with non-completion primarily due to women traveling to visit relatives or attending market days. The median home visit duration was 45 minutes (IQR: 35–55).

Fidelity of Intervention

The intervention fidelity was monitored and maintained according to the five-domain framework ('best practices') proposed by the National Institutes of Health Behavior Change Consortium [22]. These domains included: (1) standardizing the dose across all participants using a detailed session manual specifying activity timelines; (2) uniform facilitator preparation through a structured training syllabus; (3) direct observation of session delivery using supervisory checklists and session scripts; (4) gauging participant comprehension via pre- and post-session knowledge quizzes; and (5) verifying practical application of learned skills during the biweekly reinforcement visits. Supervisors independently completed fidelity checklists for 90% of the group education sessions (54 out of 60) and 85% of the home visits (102 out of 120). The mean fidelity score, expressed as the percentage of checklists executed as planned, was 87.3% (SD = 6.2) for group sessions and 85.6% (SD = 7.1) for home visits. To gauge inter-facilitator reliability, two supervisors concurrently evaluated a random 10% subset of sessions; the resulting Cohen's κ was 0.82 (95% CI: 0.74–0.89), denoting substantial agreement.

Measurement of Outcome Variable and Covariates

Nutritional Status, the outcome variable, was measured using a standard, non-stretchable Middle Upper Arm Circumference (MUAC) tape. MUAC is a reliable and simple tool used as a surrogate for Body Mass Index to monitor the nutritional status of pregnant mothers [26]. Trained data collectors took all measurements on women's left arms, strictly adhering to WHO standardized anthropometric procedures [27]. A MUAC threshold of <23 cm was used to classify women as undernourished for descriptive purposes.

Health Belief Constructs were assessed using a 27-item Likert-scale questionnaire adapted from validated instruments [28, 29]. The subscales included perceived susceptibility (4 items), perceived severity (4 items), perceived benefits (4 items), perceived barriers (5 items), self-efficacy (4 items), and cues to action (6 items). Each item was scored from 1 (strongly disagree/very unlikely) to 5 (strongly agree/very likely). Construct-specific summary scores were computed and divided into tertiles, with the highest tertile reflecting a stronger presence of a belief. Higher perceived susceptibility, severity, benefits, self-efficacy, and cues to action are associated with a greater probability of achieving the desired behavioral outcome (normal nutritional status), whereas higher perceived barriers are linked with a lower likelihood of the outcome.

Household Food Insecurity was assessed using the standard Household Food Insecurity Access Scale (HFIAS), comprising nine occurrence and nine frequency questions to characterize household food access [30]. The occurrence (experience) of a food insecurity condition was scored 1, and non-occurrence was scored 0. Any household reported at least one or more food insecurity condition in the past four weeks was classified as food insecure.

Household Wealth Index was measured using the International Wealth Index (IWI) scale, adapted to suit the study setting and ensure discriminative power [31]. IWI scale is an asset-based index used to measure a household's economic status by assessing material well-being [31]. The tool comprised 22 questions covering household assets, housing quality, water source, and sanitation facilities. Of these, 20 binary questions with scores of 1 (Yes) and 0 (No) assessed the ownership of specified assets, while two

questions evaluated the quality of the household's water supply and the toilet facility, with scores of 1 (poor quality), 2 (medium quality), and 3 (good quality). As the IWI scale assigns equal scores for all assets, which may otherwise have different values, principal component analysis was performed to generate item weights, and the resulting scores were grouped into quintiles ranging from poorest to wealthiest.

Nutrition knowledge was assessed through an 11-item questionnaire covering basic maternal nutrition during pregnancy (e.g., recommended dietary diversity and eating patterns, iron-rich foods, and iodine sources), with a correct response assigned a score of 1 and an incorrect response a score of 0. Correct responses were summed to create a total knowledge score (ranging from 0-11), which was then categorized into tertiles, with the highest tertiles representing good nutrition knowledge, the middle tertiles medium nutrition knowledge, and the lowest tertiles poor nutrition knowledge.

Additional Covariates: Data were also collected on maternal age, marital status, educational attainment, occupation, household size, living arrangement, obstetric history (parity, gravidity, and antenatal care attendance), husband's education and occupation, home garden availability, and household cash decision-making.

Data Collection Tools and Procedures

Data were gathered using a pretested, structured interviewer-administered questionnaire. The instrument encompasses sections: sociodemographic characteristics, obstetric history, HBM constructs, nutrition knowledge, eating habits and food taboos, household food insecurity, and wealth index. A dedicated section recorded all relevant anthropometric measurements. Four data collectors (holding bachelor's degrees in public health nutrition) and two supervisors (holding master's degrees) were recruited and intensively trained on methods and procedures. Data collection occurred in three phases: (1) a pre-study household survey to identify eligible participants and create the sampling frame, (2) baseline data collection, conducted immediately before the intervention, and (3) endline data collection, conducted one month after the final education session to assess outcome variables (MUAC, DDS, HBM constructs, and nutrition knowledge).

Data Quality Assurance

To guarantee semantic equivalence, the questionnaire was translated from English into Nuer and then independently back-translated by two language specialists. A five-day practical training was provided for data collectors and supervisors, covering interview techniques, anthropometric standardization, and ethical conduct. The full questionnaire was pretested on 5% of the target sample in a neighboring non-study district. Reliability and validity assessments yielded satisfactory metrics: internal consistency (Cronbach's α) for the HBM subscales ranged from 0.72 to 0.89 (threshold ≥ 0.7); content validity (Lawshe's Content Validity Ratio) ranged from 0.81 to 0.95 (threshold ≥ 0.78); and face validity (Cohen's κ) ranged from 0.65 to 0.78 (threshold ≥ 0.60). Confirmatory factor analysis confirmed the dimensional structure of the HBM scales, with goodness-of-fit indices between 0.91 and 0.95 (target ≥ 0.9).During fieldwork, data collectors reviewed each questionnaire for completeness prior to leaving the participant's household, while supervisors conducted daily random spot-checks for accuracy and consistency. For MUAC, inter-observer reliability was evaluated through duplicate measurements on a subsample; intra-class correlation coefficient reached 0.93 (exceeding the benchmark: 0.90.

Statistical Analysis

Data were entered via the Kobo Toolbox platform on Android devices and exported to

IBM SPSS Statistics 25 for analysis. Descriptive statistics: means, standard deviations, frequencies, and percentages were computed to summarize participant characteristics. Normality of continuous variables was assessed using Kolmogorov-Smirnov tests. Baseline comparability between the intervention and control groups was examined using independent t-tests for continuous variables and chi-square tests for categorical variables.

To estimate the intervention's effect on nutritional status while properly accounting for the clustered and repeated-measures nature of the data, a Linear Mixed-Effects Model (LMM) with restricted maximum likelihood estimation was employed. The model acknowledged the hierarchical data structure: repeated MUAC observations (baseline and endline) nested within individual women, who were themselves nested within kebeles (clusters). The fixed-effect component of the model included: time (baseline vs. endline), group (intervention vs. control), and the two-way interaction between time and group. This interaction term represented the difference-in-differences estimator, i.e., the average change in MUAC from baseline to endline in the intervention group relative to the control group and constituted the primary parameter of interest. The model was adjusted for covariates to control for potential residual confounding and improve precision: maternal age, educational level, household wealth quintile, family size, parity, and baseline MUAC. Random intercepts were incorporated at both the participant level (to account for within-subject correlation across the two time points) and the cluster level (to account for between-kebele variability).

Model Diagnostics and Missing Data: Model assumptions were verified by plotting standardized residuals against fitted values to check homoscedasticity and inspecting Q-Q plots to assess normality of the random effects. The Intra-cluster Correlation Coefficient (ICC) was derived from the variance components to quantify the proportion of total variance attributable to between-cluster differences. Multicollinearity among continuous predictors was examined using Variance Inflation Factors, all of which remained below 2.0, indicating no collinearity. Influential outliers were screened using Cook's distance; no value exceeded the conventional threshold of 4/n, suggesting that individual observations did not unduly influence estimates. Missing data were minimal, accounting for less than 5% of observations. A comparative analysis of baseline characteristics between participants with complete follow-up and those lost to follow-up revealed no statistically significant differences, supporting the assumption that data were missing at random conditional on the observed covariates. Under this assumption, the LMM with maximum likelihood estimation provides unbiased and efficient parameter estimates. All analyses were conducted on an intention-to-treat basis, with participants analyzed according to their original cluster allocation regardless of intervention adherence. Missing outcome data were handled using restricted maximum likelihood estimation within the LMM framework, which provides unbiased estimates under the missing-at-random assumption. To evaluate the intervention's effect on theoretical mediators, change scores (endline - baseline) were computed for each of the HBM constructs. Independent t-tests were used to compare mean change scores between the intervention and control groups. Difference-in-differences (additional change in the intervention group vs. controls) was calculated for each construct, along with 95% CIs and p-values, allowing measurement of the extent to which the intervention modified health beliefs.

Mediation Analysis: To formally test whether changes in HBM constructs mediated the intervention effect on MUAC, a mediation analysis was conducted using a bootstrapping approach with 5,000 resamples: Hayes

PROCESS macro v4.0 for SPSS [32]. Because causal mediation requires temporal precedence, the intervention group (X) was modeled as the independent variable, endline HBM construct scores as mediators (M), and endline MUAC as the outcome (Y), adjusting for baseline values of both the respective HBM construct and baseline MUAC. This approach establishes temporal ordering (intervention → endline mediator → endline outcome, conditional on baseline values) and is consistent with modern recommendations for longitudinal mediation. Given that six HBM constructs were tested as individual mediators, a conservative Bonferroni correction was applied for the individual mediator tests ($\alpha = 0.05/6 = 0.0083$) to control Type I error. Individual mediation effects with p-values below 0.0083 were considered statistically significant. The combined model (all six mediators simultaneously) was evaluated at $\alpha = 0.05$, as it represents a single omnibus test of the mediation pathway.

Effect Reporting: Adjusted mean differences (β coefficients) were presented with their 95% confidence intervals and corresponding p-values derived from Wald tests. To facilitate clinical interpretation, Estimated Marginal Means (EMMeans) were computed for MUAC in each group at each time point, adjusted for all covariates. Within-group and between-group contrasts were compared using pairwise comparisons with Least Significant Difference (LSD) adjustment. A two-sided significance level of $\alpha = 0.05$ was applied to hypothesis tests.

Results

Socioeconomic Characteristics and Comparability

The baseline socioeconomic and nutritional profiles of the intervention and control groups were comparable across all measured characteristics (Table 1). A total of 328 pregnant women participated in the study (164 in each arm). The mean age was 28.1 years (SD 4.6), mean household size was 5.3 members (SD 2.0), and baseline MUAC was nearly identical for the intervention and control groups (24.08 cm vs. 24.28 cm). Educational attainment, occupational distribution, household food insecurity, and nutrition knowledge were similarly balanced between arms, with no statistically significant differences ($p > 0.05$ for all comparisons). The mean gestational age was 13.8 weeks (SD 3.2) in the intervention group and 14.6 weeks (SD 3.5) in the controls. Follow-up completion was high in both groups: 162/164 (98.8%) in the intervention and 159/164 (97.0%) in the control arm. Loss to follow-up was due to relocation (intervention: n = 1; control: n = 3) and withdrawal of consent (intervention: n = 1; control: n = 2), with no losses due to adverse events. Baseline characteristics did not differ between completers and non-completers ($p > 0.05$), supporting the assumption of missing data at random (Table 1).

Table 1. Baseline Socioeconomic Characteristics of Participants and Comparability by Study Group in Nuer Zone, Gambella Region, Western Ethiopia, 2026

Characteristics	Category	Intervention	Control	P value
		N (%)	N (%)	
Age (years)	Mean (±SD)	28.3 (4.5)	27.9 (4.8)	0.487
Age at first marriage	Mean (±SD)	18.4 (3.8)	18.1 (4.2)	0.499
Family size	Mean (±SD)	5.2 (1.9)	5.4 (2.1)	0.739
Baseline MUAC (cm)	Mean (±SD	24.08 (1.71)	24.28 (1.68)	0.285
Marital status	Married & live together	57 (34.8)	55 (33.5)	0.937
	Separated	56 (34.1)	55 (33.5)	
	Divorced	51 (31.1)	54 (32.9)	

Education of respondent	Secondary & above	86 (52.4)	85 (51.8)	0.917
	Primary (1–8)	42 (25.6)	40 (24.4)	
	No formal education	36 (22.0)	39 (23.8%)	
Occupation of respondent	Employee	39 (23.8)	44 (26.8)	0.254
	Merchant (trader)	41 (25.0)	36 (22.0)	
	Farmer	39 (23.8)	51 (31.1)	
	Daily laborer	45 (27.4)	33 (20.1)	
Education of husband	Secondary & above	86 (52.4)	74 (45.1)	0.295
	Primary (1–8)	34 (20.7)	45 (27.4)	
	No formal education	44 (26.8)	45 (27.4)	
Occupation of husband	Employee	40 (24.4)	38 (23.2)	0.168
	Merchant	49 (29.9)	34 (20.7)	
	Farmer	37 (22.6)	40 (24.4)	
	Daily laborer	38 (23.2)	52 (31.7)	
Nutrition knowledge	Low	72 (43.9)	77 (47.0)	0.833
	Medium	47 (28.7)	46 (28.0)	
	High	45 (27.4)	41 (25.0)	
Household food security	Food secure	88 (53.7)	79 (48.2)	0.32
	Food insecure	76 (46.3)	85 (51.8)	
Household wealth status	Poorest	33 (20.1)	31 (18.9)	0.96
	Poorer	32 (19.5)	30 (18.3)	
	Middle	23 (14.0)	26 (15.9)	
	Richer	39 (23.8)	39 (23.8)	
	Richest	37 (22.6)	38 (23.2)	
Dietary diversity	Inadequate	124 (75.9)	120 (73.0)	0.542
	Adequate	40 (24.1%)	44 (27.0)	
Cash decision maker	Husband	41 (25.0)	43 (26.2)	0.876
	Wife	72 (43.9)	66 (40.2)	
	Joint	44 (26.8)	47 (28.7)	
	Others	7 (4.3)	8 (4.9)	
Living arrangement	Nuclear	112 (68.3)	107 (65.2)	0.613
	Joint/Extended	49 (29.9)	51 (31.1)	
	Others	3 (1.8)	6 (3.7)	
Home garden available	No	35 (21.3)	28 (17.1)	0.337
	Yes	129 (78.7)	136 (82.9)	
Parity	Nulipara	26 (15.9)	24 (14.6)	0.9
	1–3	89 (54.3)	88 (53.7)	
	≥4	49 (29.9)	52 (31.7)	
Mean gestational age	Mean (±SD)	13.76	14.61	0.1

SD: Standard Deviation, MUAC: Middle-Upper Arm Circumference

Effect of Nutrition Education on Maternal Nutritional Status

At baseline, the prevalence of undernutrition (MUAC < 23 cm) was comparable between intervention and control groups (30.2% vs. 24.5%, respectively; p = 0.285), and mean MUAC values were similar (24.08 cm and 24.28 cm, p = 0.285). At the endline, the intervention group demonstrated marked improvement, with undernutrition prevalence declining to 5.6% and mean MUAC increasing to 25.41 cm (SD 1.65). Conversely, the control group showed deterioration, with undernutrition rising to 26.4% and mean MUAC declining to 23.83 cm (SD 1.06). The between-group differences were significant for both prevalence (20.8 percentage points, $\chi^2 = 28.9$, $p < 0.001$, number needed to treat = 5) and continuous MUAC (1.587 cm, $p < 0.001$). The Difference-in-Differences (DiD) estimate of 1.789 cm (95% CI: 1.485–2.093, $p < 0.001$) confirms that the intervention conferred a substantial protective effect on maternal nutritional status, effectively reversing the declining trend observed in the control group. These findings indicate that the intervention was associated with meaningful improvements in nutritional status, supporting its potential for broader implementation (Table 2).

Table 2. Differences in Mean MUAC Measurement by the Group over the Study Period in Nuer Zone, Gambella Region, Western Ethiopia, 2026

Variable	Study Period	Intervention	Control	t-test	Mean Difference	P-value
		Mean ± SD	Mean ± SD		(Intervention – Control) ± SE	
MUAC (cm)	Baseline	24.080 ± 1.711	24.282 ± 1.679	–1.071	–0.203 ± 0.189	0.285
	End line	25.414 ± 1.648	23.827 ± 1.063	10.23	1.587 ± 0.155	<0.001
	Difference (EL – BL)	1.334	–0.455	–	1.789 (DiD)	< 0.01

BL: Baseline, EL: End line, SD: Standard Deviation, SE: Standard Error

Within and Between Group Changes in Health Belief Model Constructs

Table 3 presents the within-group changes in HBM constructs from baseline to endline. The intervention group demonstrated substantial positive changes across all six constructs, with the largest improvements observed in perceived benefits (+5.97), perceived barriers (–4.79), and cues to action (+3.94). In contrast, the control group showed minimal changes, with small increases in perceived benefits (+3.37) and self-efficacy (+1.14), and a slight decline in perceived susceptibility (–0.21). The difference-in-differences (DiD) between groups was highly significant for all constructs (p-values < 0.001), with the largest between-group difference observed for perceived barriers (–4.49, 95% CI: –4.95 to –4.03) and perceived severity (+3.38, 95% CI: 2.88–3.88). Note: A negative sign signifies a reduction in score.

Table 3. Changes in Mean HBM Constructs from Baseline to Endline by Study Group in Nuer Zone, Gambella Region, Western Ethiopia, 2026

Construct	Intervention	Control	Mean Difference (I – C)	95% CI	P-value
Perceived Susceptibility	2.57	–0.21	2.78	(2.31, 3.25)	<0.001
Perceived Severity	3.78	0.4	3.38	(2.88, 3.88)	<0.001
Perceived Benefits	5.97	3.37	2.6	(2.14, 3.06)	<0.001

Perceived Barriers	–4.79	–0.30	–4.49	(–4.95, –4.03)	<0.001
Self-efficacy	2.4	1.14	1.26	(0.86, 1.66)	<0.001
Cues to Action	3.94	0.32	3.62	(3.05, 4.19)	<0.001

Mediation of HBM Constructs in Intervention's Effect on MUAC

To examine the mechanisms through which the intervention improved MUAC, mediation analysis was conducted using endline HBM construct scores as mediators and endline MUAC as the outcome, adjusted for baseline values of both the respective HBM construct and baseline MUAC (Table 4). The total intervention effect on MUAC was 1.789 cm ($p < 0.001$). All six HBM constructs emerged as significant mediators, with perceived barriers reduction mediating the largest proportion of the total effect (43.6%, indirect effect = 0.78, 95% CI: 0.51–1.07), followed by perceived severity (39.1%, indirect effect = 0.70, 95% CI: 0.42–1.02) and cues to action (34.1%, indirect effect = 0.61, 95% CI: 0.35–0.91). When all six mediators were included simultaneously in the model, the combined indirect effect was 0.92 (95% CI: 0.68–1.18), accounting for 51.4% of the total effect. This suggests that changes in health beliefs and self-efficacy explain approximately half of the intervention's impact on maternal nutritional status, with the remaining effect potentially operating through other unmeasured pathways or direct behavioral changes (Table 4).

Table 4. Mediation of HBM Constructs in the Intervention's Effect on MUAC Among Pregnant Women in Nuer Zone, Gambella Region, Western Ethiopia, 2026

Mediator (Change Score)	Direct Effect	Indirect Effect	Total Effect	Proportion Mediated	95% CI
Perceived Susceptibility	1.21	0.58**	1.79***	32.40%	(0.31, 0.89)
Perceived Severity	1.09	0.70***	1.79***	39.10%	(0.42, 1.02)
Perceived Benefits	1.23	0.56**	1.79***	31.30%	(0.28, 0.85)
Perceived Barriers (↓)	1.01	0.78***	1.79***	43.60%	(0.51, 1.07)
Self-Efficacy	1.34	0.45*	1.79***	25.10%	(0.18, 0.72)
Cues to Action	1.18	0.61***	1.79***	34.10%	(0.35, 0.91)
Combined Model	0.87	0.92***	1.79***	51.40%	(0.68, 1.18)

** P-value < 0.05, ** P-value < 0.01, *** P-value < 0.001, Reduction (↓)*

Linear Mixed-Effects Model

Table 5 presents the fully adjusted Linear Mixed–Effects Model examining the intervention effect on MUAC. The intervention conferred a significant net improvement in MUAC ($\beta = 1.789$, 95% CI: 1.485–2.093, $p < 0.001$). The random effects components revealed that 3.2% of the total variance in MUAC was attributable to between-cluster (kebele) differences, 61.9% was due to between-participant variability, while 34.8% reflected within-participant changes over time. Model building was guided by AIC/BIC, and the final model demonstrated the best fit (AIC = 2086.4, BIC = 2135.6) (Table 5).

Table 5. Linear Mixed-Effects Model for the Effect of Nutrition Education Intervention on MUAC Among Pregnant Women in Nuer Zone, Gambella Region, Western Ethiopia, 2026

Fixed Effects	β Coefficient	95% CI	SE	p-value
Intervention Effects				
Time (End line vs. Baseline)	–0.455	(–0.662, –0.248)	0.106	<0.01
Group (Intervention vs. Control)	–0.202	(–0.573, 0.169)	0.189	0.285
Intervention effect	1.789	(1.485, 2.093)	0.155	<0.01
Covariates				
Baseline MUAC (cm)	0.961	(0.942, 0.980)	0.01	<0.01
Random Effects	Variance	ICC		
Between-cluster (kebele)	0.056	0.032		
Between-participant (intercept)	1.081	0.619		
Random Slope for Time	0.016	0.009		
Residual	0.608	0.348		
Model Fit				
AIC	2086.4			
BIC	2135.6			

AIC: Akaike Information Criterion, BIC: Bayesian Information Criterion, CI: Confidence Interval, ICC: Intra-class Correlation Coefficient, SE: Standard Error

Note: *Values are regression coefficients (β) from a mixed-effects linear regression model. The model was adjusted for baseline variables. Random effects included between-cluster (kebele) variance, between-participant intercept variance, random slope for time, and residual variance. All VIFs were <2.0, confirming no problematic multicollinearity.*

Discussion

This community-based cluster-randomized controlled trial evaluated the effect of a nutrition education intervention based on the Health Belief Model on the nutritional status of pregnant women in rural western Ethiopia. The intervention in this study resulted in a statistically significant improvement in MUAC, with a net Difference-in-Differences (DiD) of 1.789 cm ($p < 0.01$) between the intervention and control groups. The observed improvement in MUAC is noteworthy in the context of maternal nutrition in rural Ethiopia. MUAC is a validated indicator of nutritional status during pregnancy, and the positive change observed in the intervention group, contrasted with a decline in the controls, suggests that the intervention may have helped women maintain or improve their nutritional reserves during a critical period. This pattern of improvement in the intervention group alongside deterioration in the control group is particularly meaningful, as it indicates that the intervention not only promoted positive change but may have also protected against the typical nutritional decline in resource-limited settings. The decline in MUAC observed in the control group (0.455 cm) is consistent with findings from the West Gojam trial, where control group participants experienced a reduction in MUAC over the course of pregnancy [33]. This pattern likely reflects the increased physiological demands of pregnancy coupled with inadequate dietary intake, which is common in resource-limited settings. The intervention appears to have not only prevented this decline but also reversed it, resulting in a net difference of 1.789 cm in MUAC. This protective effect is particularly meaningful, as it suggests that theory-driven nutrition education helped women maintain nutritional reserves during a period of heightened vulnerability. The 1.789 cm net improvement in MUAC corresponds to a

clinically meaningful reduction in undernutrition prevalence. Using the standard MUAC cut-off of <23 cm, the intervention reduced the proportion of undernourished women from 30.2% at baseline to 5.6% at endline, whereas the control group experienced an increase in undernutrition prevalence from 24.5% to 26.4%. This translates to a Number Needed to Treat (NNT) of 5 to prevent one case of maternal undernutrition. These findings suggest the intervention helped women cross the clinical threshold of adequate nutritional reserves. These findings are broadly consistent with previous studies in Ethiopia. A recent systematic review reported that nutrition education interventions were associated with improvements in MUAC among pregnant women, with community-based theory-driven approaches showing larger effects [34]. A cluster-randomized trial in West Gojam of Amhara region reported a significant reduction in undernutrition prevalence among intervention group participants [33]. Similarly, the finding is consistent with a quasi-experimental study in Southern Afghanistan that evaluated the effectiveness of an HBM-based educational intervention on iron-folic acid (IFA) supplement intake among pregnant women [35]. This consistency of findings across settings: highland agricultural zones, urban areas, and our lowland agro-pastoral context suggest that theory-based nutrition education may be a transferable strategy for improving maternal nutrition in Ethiopia.

The mediation analysis revealed that changes in HBM constructs collectively accounted for approximately half (51.4%) of the intervention effect on MUAC improvement. This finding supports the theoretical framework underpinning the intervention and offers insights into which beliefs may be most important for driving behavior change. Perceived barriers reduction emerged as the strongest mediator, accounting for 43.6% of the total effect. This is consistent with the HBM's theoretical premise that perceived barriers are among the strongest predictors of behavior change. In rural Ethiopia, barriers to adequate nutrition during pregnancy are pervasive, including limited food availability, economic constraints, cultural food taboos, and competing household demands. Our intervention appears to have been particularly effective in addressing these barriers through practical problem-solving during home visits, where women received individualized support to identify and overcome obstacles to dietary improvement. Perceived severity was the second strongest mediator (39.1%), suggesting that enhancing women's understanding of the serious consequences of undernutrition for themselves and their offspring was an important pathway for influencing nutritional status. The present findings contrast with those of a cluster-randomized trial in Southeast Ethiopia, which found no significant indirect effects through distal mediators including dietary diversity, food security, and nutrition knowledge, whereas our analysis demonstrated a significant indirect effect through proximal HBM constructs [36]. This discrepancy suggests that theory-anchored psychological beliefs are more sensitive mediators of intervention-induced change than behavioral proxies. Second, the present results align with evidence from Tanzania and Malawi, where perceived barriers, particularly cost, accessibility, and cultural constraints, and perceived severity were consistently identified as key determinants of dietary practices and adherence [37]. Together, these comparisons indicate that while distal behavioral indicators may fail to capture mechanistic pathways, proximal HBM constructs, particularly perceived barriers and perceived severity, consistently emerge as critical mediators of maternal nutrition behaviors across sub-Saharan African settings. Several methodological strengths and limitations warrant consideration. This cluster-

randomized controlled design provides strong evidence for causality, and the high fidelity of intervention delivery (87-88%) strengthens confidence in the internal validity of the trial. The inclusion of mediation analysis represents a methodological strength, providing insights into the mechanisms of change that are often lacking in nutrition intervention studies. However, some limitations should be acknowledged. The study was conducted in a single zone, which may limit generalizability to other regions of Ethiopia with different socioeconomic, cultural, and ecological contexts. The relatively short follow-up period (three months) precludes assessment of long-term sustainability of the intervention effects. The inability to blind participants is an inherent limitation of educational interventions, and self-reported measures of HBM constructs may have introduced social desirability bias. The mediation analysis, while informative, is observational and subject to unmeasured confounding; the use of change scores does not fully address the issue of temporal precedence, and measurement error in self-reported mediators may have attenuated the estimated indirect effects.

Implications for Practice and Policy

The findings suggest that theory-driven, community-based nutrition education may be an effective strategy for improving maternal nutrition in rural Ethiopia. The observed mediating role of HBM constructs, particularly perceived barriers and perceived severity, offers practical guidance for intervention design. Programs that incorporate strategies to identify and address practical barriers to dietary improvement, while also communicating the serious consequences of undernutrition in culturally appropriate ways, may be more effective than generic nutrition education. The involvement of health extension workers in delivering the intervention aligns with Ethiopia's Health Extension Program and demonstrates the potential of this platform for delivering effective nutrition interventions at scale.

Conclusions

This trial provides evidence that a Health Belief Model-based nutrition education intervention was associated with significant improvement in the nutritional status of pregnant women in rural western Ethiopia. The intervention effect appeared to be partially mediated through changes in health beliefs, particularly perceived barriers and perceived severity. These findings support the integration of theory-driven behavior change approaches into maternal nutrition programming in Ethiopia and similar settings. However, further research is needed to confirm these findings in other populations and settings and to evaluate long-term sustainability and cost-effectiveness.

Data Sharing

Data are available on reasonable request from the corresponding author.

Conflict of Interest

The authors declare that they have no competing interests.

Ethical Considerations

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki [38], and the Ethiopian National Research Ethics Review Guidelines of 2014 [39]. Ethical approval was obtained from the Institutional Review Board of the Gambella Peoples National Regional State Health Bureau. Additional administrative permissions were obtained from the Nuer Zone Health Office and the respective district health authorities. All eligible women were given comprehensive information about the study’s purpose, procedures, potential risks, and anticipated benefits. Written informed consent was obtained from each participant before enrolment; for women unable to read or write, an impartial community witness was present throughout the consent process. Participants

were explicitly informed that their involvement was entirely voluntary and that they could discontinue participation at any point without any negative repercussions for their routine healthcare. To protect confidentiality, all data were anonymised using unique participant identification codes, and electronic data were stored on password-protected, encrypted computers accessible only to the core research team. Women identified as undernourished (MUAC < 23 cm) or presenting with other health concerns were immediately referred to the nearest primary health facility for appropriate management. As an ethical gesture of beneficence, the control group was offered the complete educational materials and a condensed version of the intervention after the end line survey had been finalized. The study findings will be disseminated to the participating communities, local health authorities, and the regional health bureau to guide evidence-based maternal nutrition programming.

Authors' Contribution

The authors' contributions were evaluated based on the following components: Conception and Design, Execution (Data Acquisition), Analysis and Interpretation, and Manuscript Preparation (Drafting and Finalization). The corresponding author contributed to all of these phases of the research project, while other authors contributed to Conception and Design, Interpretation, and Manuscript Revision and agreed to publication in this journal.

Acknowledgement

We would like to thank Texila American University (TAU) and the University of Central Nicaragua (UCN) for their institutional leadership and guidance. We are indebted to everyone contributed technically or administratively to the success of our research project. Specifically, we appreciate data collectors and intervention facilitators for their effective work. Last but not least, we are grateful to the participants for volunteering to participate in the study.

Funding

The authors received no funding.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art018

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Contextual Factors Undermining Community Health Worker Data Systems During Health Emergencies in Zimbabwe: A Cross-Cadre Survey Analysis

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Cite this article as: Tafadzwa Dzamara. Contextual factors undermining community health worker data systems during health emergencies in Zimbabwe: a cross-cadre survey analysis. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art018**

Received: 26.08.2026

Accepted: 06.10.2026

Published: 30.10.2026

Article Type: Original Research

Abstract *Community health workers (CHWs) are central to community surveillance and primary health care in Zimbabwe, yet the data systems supporting their work are especially vulnerable during epidemics, cyclones and other health emergencies. This study examined the contextual factors undermining the collection, transmission, verification and use of CHW data during health emergencies in Zimbabwe between 2018 and 2025 and identified priorities for strengthening system resilience. A cross-sectional, multi-cadre structured survey was administered through Kobo Toolbox to 142 respondents across eleven cadres spanning the community, facility, district and provincial levels of the health system. Respondents reported near-universal involvement in emergency-related data work (95.0%) and described data roles as clearly defined (89.3%), but only 67.1% could still transmit data when electricity or internet connectivity failed. Data collection was the most disrupted stage of the CHW data pathway (30.7%), and tools and devices (67.6%) together with power and connectivity (58.5%) were the factors most often blamed for undermining continuity. Only 33.6% rated emergency-specific training as adequate, and overall data timeliness and quality was rated good or very good by 48.6% of respondents, falling to 40% among community-level respondents. Respondents' priorities for the Ministry of Health and Child Care centred on infrastructure investment (32.9%) and workforce training (30.0%). The findings indicate that Zimbabwe's community health information system is broadly functional at its technical core but remains constrained at the point of community-level data capture, pointing to sequenced, practical investment priorities for strengthening emergency-responsive CHW data systems.*

Keywords *Community Health Workers, Data Systems, Health Emergencies, Health Information systems, Health System Resilience, Zimbabwe.*

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Introduction

Community Health Workers occupy a distinctive position at the interface between the formal health system and the community, and it is this position that makes their data uniquely valuable, especially during health emergencies [1]. In Zimbabwe, the Community Health Worker programme, which traces its lineage to the Village Health Worker programme of the 1980s, has been consolidated under a "one health worker" model within the 2026–2030 National Health Strategy, and CHWs remain a central pillar of the country's primary health care system [2, 3]. During disease outbreaks and disasters, CHWs are frequently the first to detect, record and report unusual events at household and village level, making their data systems an early-warning and situational-awareness resource of national importance [4].

However, the same emergencies that elevate the importance of CHW data also place unusual strain on the systems used to collect, transmit, verify and act on that data. Zimbabwe's experience with the 2018 and 2023 cholera outbreaks, Cyclone Idai in 2019 and the COVID-19 pandemic illustrates a recurring pattern in which community-level reporting becomes fragmented, delayed or incomplete precisely when demand for real-time information is highest [5, 6]. During the COVID-19 response, the Ministry of Health and Child Care, working with the World Health Organization and partners, sought to strengthen a weekly routine monitoring system linked to the District Health Information System in order to maintain data-driven decision-making, an initiative that itself signalled the pre-existing gaps in emergency-responsive community data flows [7].

Globally and across sub-Saharan Africa, evidence indicates that community-based health information systems are disproportionately vulnerable during crises. A four-country interrupted time series analysis found that continuity of community-based care during COVID-19 depended heavily on how well CHWs were remunerated, supplied and supervised prior to the shock [8]. Similarly, comparative work across the Democratic Republic of Congo, Nigeria, Senegal and Uganda documented that CHWs were central to COVID-19 surveillance and response, but that their data and reporting roles were constrained by weak connectivity, inadequate protective and reporting supplies, and limited integration with national systems [9]. These findings resonate with Zimbabwe's own digital health trajectory, where investment in platforms such as Impilo has expanded electronic health record functionality, but persistent barriers to electricity, internet connectivity, and human resource capacity continue to constrain reliable data generation, particularly in rural and emergency-affected districts [10, 11].

This paper reports a mixed-methods doctoral study, combining a cross-cadre quantitative survey with a parallel qualitative strand, that examined the contextual factors, infrastructural, institutional, technological and sociocultural, that undermine the functioning of CHW data systems specifically during health emergencies in Zimbabwe. The analysis presented here draws on the quantitative survey strand, administered to 142 health workers and system managers with direct experience of CHW data work during recent emergencies. In doing so, it moves beyond the routine, non-crisis framing that dominates much of the existing monitoring and evaluation literature on CHW programmes and generates context-specific evidence to inform the design of data systems that remain functional under conditions of acute stress.

Background and Zimbabwean Context

The Community Health Worker cadre in Zimbabwe was established to extend primary health care to underserved rural and peri-urban populations and has since been mobilised repeatedly during public health emergencies, including cholera outbreaks, floods and cyclones, and the COVID-19 pandemic [3]. Historically, community-level reporting relied

on paper-based registers and monthly aggregate returns submitted through district health offices into the national health information system. While Zimbabwe has progressively introduced digital tools, including mobile data collection and the Impilo electronic health record platform, the transition remains incomplete and uneven across the country's ten provinces [10, 11].

Zimbabwe faces a recurrent and diverse hazard profile, including epidemics such as cholera and typhoid, extreme weather events, and disease pandemics, a profile that has driven the recent establishment of Public Health Emergency Operations Centres to coordinate multisectoral response [3]. Each of these emergencies has generated evidence of strain on community-level data systems. The 2023 cholera outbreak, which began in Chegutu and spread to seventeen hotspot districts across all ten provinces, required rapid case-based surveillance and community-level case detection, yet response reviews point to continuing challenges of standardisation, timeliness and resource availability in outbreak data management [12, 13]. Descriptive epidemiological analysis of the earlier 2018-2019 cholera outbreak similarly emphasised that effective epidemic control depended on a functioning multisectoral surveillance architecture, reinforcing that community reporting gaps have long been a recognised vulnerability rather than a new phenomenon [5].

During the COVID-19 pandemic, essential health services, including those delivered and reported on by CHWs, were disrupted across Zimbabwe and the wider sub-Saharan African region, with the World Health Organization estimating that the majority of countries experienced disruption in at least one essential health service [9]. In Zimbabwe specifically, the Ministry of Health and Child Care worked with WHO and partners to reinforce weekly routine monitoring tied to the District Health Information System precisely because pre-existing community reporting mechanisms had proved insufficiently resilient to sustain service continuity monitoring under pandemic conditions [7].

Evidence from Zimbabwe and comparable settings converges on several recurring categories of contextual barriers. Infrastructural constraints, including unreliable electricity and limited internet and mobile network coverage, restrict the reach of digital and cloud-based reporting tools, with power shortages alone estimated to cost the Zimbabwean economy the equivalent of 6.1 percent of gross domestic product annually and directly affecting facility and community data connectivity [11]. Interoperability challenges, arising from parallel, poorly linked information systems, compound these infrastructural gaps; a scoping review of digital health interventions across Ethiopia, Ghana and Zimbabwe found that fragmented systems and limited technical integration reduce the extent to which community-generated data can be aggregated and used for decision-making at higher levels [10].

Workforce-related barriers are equally prominent. Evidence from Ethiopia's electronic community health information system found that health worker digital literacy, resistance to new tools, inadequate training, and limited trust among stakeholders operating parallel systems each independently constrained routine data quality, patterns that are plausible analogues for Zimbabwe's CHW cadre operating under the added pressure of emergency conditions [1, 4]. Institutional and governance-related barriers, including weak feedback loops between community and higher-level data users, insufficient supervision, and unclear coordination mechanisms during multisectoral emergency response, further limit the extent to which community data translate into timely action [4]. Finally, sociocultural and contextual factors, including community trust, language diversity, and the seasonal and geographic accessibility of remote study and reporting

sites, shape both the willingness of communities to engage with CHWs during crises and the practical feasibility of consistent reporting [3].

Problem Statement

Despite the centrality of Community Health Workers to Zimbabwe's emergency response architecture, and despite ongoing national investment in digitising health information systems, there has been limited systematic, context-specific evidence on the factors that undermine the functioning of CHW data systems specifically during health emergencies, as opposed to during routine, non-crisis programme implementation. Existing assessments have tended to focus either on general monitoring and evaluation weaknesses in the CHW programme, or on outbreak-specific epidemiological review, without an integrated examination of the infrastructural, institutional, technological and sociocultural contextual factors that interact to weaken community-level data systems precisely when their reliability is most critical. This gap constrains the ability of the Ministry of Health and Child Care and its partners to design CHW data systems that remain functional and trustworthy under conditions of acute stress, and it is this gap that the present study addresses.

Study Objective and Research Questions

The study aimed to examine the contextual factors that undermine the functioning of community health worker data systems during health emergencies in Zimbabwe and to inform the design of more resilient, emergency-responsive community health information systems. It was guided by five questions: how community health worker data systems operate and adapt during declared emergencies; which infrastructural and technological barriers constrain data collection, transmission and use; how institutional and governance arrangements shape system performance; which sociocultural and community factors influence data completeness and reliability; and which strategies could strengthen resilience before, during and after future emergencies. The cross-cadre survey reported in this article speaks most directly to the second, third and fourth of these questions, providing structured, quantifiable evidence on infrastructural, institutional and sociocultural barriers across the data pathway; the first and fifth questions, concerning adaptive practice and forward-looking strategy, are being addressed jointly with the parallel qualitative interview and focus-group strand of the wider study.

Policy Relevance, Scope and Novelty

The study is directly relevant to Zimbabwe's 2026-2030 National Health Strategy and to the World Health Organization's Health Emergency Prevention, Preparedness, Response and Resilience (HEPR) framework, launched at the Seventy-sixth World Health Assembly in 2023, both of which emphasise strengthening national and community-level information systems as a pillar of emergency preparedness [6]. Findings provide evidence to inform the operationalisation of Zimbabwe's Public Health Emergency Operations Centres, which depend on timely, quality community-level data to function as effective coordination hubs [3].

Although the global literature on CHW programmes and on digital community health information systems has expanded considerably in recent years [1, 4], comparatively little of this evidence is specific to the emergency context, and even less is grounded in Zimbabwe's own experience across cholera outbreaks, cyclones and the COVID-19 pandemic. This study addresses that gap by generating context-specific, emergency-focused evidence rather than extrapolating from routine-period studies.

Recurrent cholera outbreaks, including the 2023 outbreak that resulted in nearly 5,000 confirmed and suspected cases and

approximately 100 deaths in Chegutu district alone, illustrate the direct public health cost of delayed or incomplete community-level surveillance data [12]. By identifying the contextual factors that undermine CHW data systems during such emergencies, the study is expected to generate practical, implementable recommendations capable of reducing detection and response delays in future outbreaks and disasters, thereby contributing to the protection of lives and the more efficient allocation of emergency health resources.

The study is confined to Zimbabwe's Community Health Worker programme and focuses specifically on the health-emergency context, drawing on the experience of stakeholders involved in the response to recent cholera outbreaks, Cyclone Idai and the COVID-19 pandemic. As a purposive, non-probability survey nested within a broader case-study design, the findings provide descriptive, context-specific evidence rather than nationally representative statistical estimates; transferability beyond the surveyed provinces and cadres will depend on the similarity of health-system architecture and emergency profile. Recall bias associated with retrospective accounts of past emergencies is a further limitation, which the study sought to mitigate through the breadth of cadres and emergency types sampled and, in the parallel qualitative strand, through triangulation with programme documents and situation reports. Access to some rural and emergency-affected sites was constrained by seasonal conditions; data collection was therefore scheduled to avoid the peak rainy season, and remote data-collection options were offered where physical access remained restricted.

The novelty of the study lies in analysing community health worker data systems as emergency-response infrastructure rather than only as routine monitoring mechanisms, and in doing so through a structured, multi-cadre survey that spans the full data pathway, from community-level collection through facility, district and provincial use. By integrating health-system resilience and implementation-science perspectives, the study examines how technical, organisational, workforce and community conditions interact under acute stress.

Theoretical and Conceptual Framework

The study is anchored in the World Health Organization's health systems resilience framework, which conceptualises resilience as the capacity of a health system to absorb, adapt to and transform in response to shocks while maintaining core functions, including the generation and use of health information [14]. Applied to CHW data systems, this framework directs attention to the extent to which community-level data infrastructure, workforce and governance arrangements are able to withstand and adapt to the surges in demand and disruption in supply that accompany health emergencies, rather than assuming that systems designed for routine conditions will automatically perform under crisis conditions.

Building on the conceptualisation by Kok et al. [15] of CHW performance as embedded within a layered health system comprising "hardware" (infrastructure, supplies, technology and formal governance structures) and "software" (relationships, trust, values and informal norms), this study conceptualises CHW data system performance during emergencies as shaped by the dynamic interaction of four contextual domains: infrastructural and technological factors, institutional and governance factors, workforce-related factors, and sociocultural and community factors. Each domain is understood to interact with the others, and their combined configuration under emergency conditions is expected to determine whether CHW data systems remain functional, degrade, or fail during a given crisis. These four domains directly informed the design of the cross-cadre survey instrument, structuring both the common questions asked of every respondent

and the cadre-specific items described below. Table 1 summarises the contextual domains that guided data collection and analysis.

Table 1. Contextual Domains Guiding Data Collection and Analysis

Contextual Domain	Illustrative Factors	Relevance to Emergency Data Systems
Infrastructure and technology	Electricity, connectivity, devices and interoperability	Determines whether reporting tools function under surge conditions
Institutions and governance	Supervision, feedback, coordination and emergency-operations linkages	Shapes whether data are verified, aggregated and acted upon
Workforce	Training, digital literacy, workload, motivation and safety	Affects data accuracy, completeness and timeliness at source
Sociocultural and community	Trust, language, stigma and geographical accessibility	Influences reporting, participation and household reach

Materials and Methods

Study Design and Setting

The study adopted a mixed-methods design nested within a broader doctoral research programme investigating the contextual factors that undermine CHW data systems during health emergencies in Zimbabwe. This article reports the quantitative strand: a cross-sectional, multi-cadre structured survey administered to health workers and system managers who had direct experience of collecting, managing, supervising or using CHW data during major health emergencies in Zimbabwe between 2018 and 2025, including the 2018-2019 and 2023 cholera outbreaks, Cyclone Idai and the COVID-19 pandemic [5, 8, 9, 12, 13]. A parallel qualitative strand, comprising semi-structured interviews and focus group discussions with a purposively selected subset of informants and analysed using reflexive thematic analysis [16] against established qualitative trustworthiness criteria [17], is being conducted to provide rich, context-embedded description of how and why contextual factors undermine CHW data systems; it is referenced here only where it shaped the conceptual framework and instrument design, and its findings will be reported separately. The exploratory case-study framing common to both strands allowed triangulation across multiple emergency events while remaining sensitive to the distinct characteristics of each emergency type [18].

Respondents were drawn from provinces with documented emergency exposure during the study period. Most respondents reported experience based in Mashonaland East (57 respondents, 40.1% of the 140 who completed the core sections) and Midlands (42, 29.6%), with smaller numbers from Matabeleland South (12), Matabeleland North (7), Masvingo (6), Mashonaland West (6), Manicaland (4), Harare (3) and Mashonaland Central (3). The predominance of rural settings among respondents' primary emergency experience reflects the rural distribution of Zimbabwe's CHW programme and of its highest-burden emergency-affected districts.

Study Population and Sampling

The study population comprised Community Health Workers, community and facility nurses, laboratory and environmental health technicians, district and provincial monitoring, information and nursing officers, and a national-level laboratory services official, all involved in CHW programme data management and drawn from areas that experienced significant health emergencies between 2018 and 2025. A purposive, maximum-variation sampling strategy was used [18], targeting variation in cadre, health-system level and emergency exposure. A total of 142 respondents completed one of eleven cadre-specific structured questionnaires: 48 Community Health Workers (33.8%), 40 Facility Nurses in Charge (28.2%), 24 District Health Information Officers (16.9%), 11 Environmental Health Technicians (7.7%), 5 Provincial Monitoring and Evaluation Officers (3.5%), 4 Laboratory Technicians (2.8%), 4 Community Nurses (2.8%), 2 Provincial Laboratory Scientists (1.4%), 2 District Nursing Officers (1.4%), 1 Provincial Pharmacist (0.7%) and 1 Deputy Director of Laboratory Services (0.7%) (Table 2). For cross-cutting comparisons, cadres were grouped into four health-system levels: community level (Community Health Workers and Community Nurses, n = 52), facility level (Facility Nurses in Charge, Laboratory Technicians and Environmental Health Technicians, n = 55), district level (District Health Information Officers and District Nursing Officers, n = 26), and provincial or national level (Provincial Monitoring and Evaluation Officers, Provincial Pharmacists, Provincial Laboratory Scientists and the Deputy Director of Laboratory Services, n = 9). All 142 respondents gave informed consent to take part; two did not complete the substantive sections beyond the consent stage, so most pooled results are reported out of 140. Frontline and facility-level cadres accounted for 79% of the sample, while several provincial and specialist cadres had very small counts of one or two respondents; findings for these small cadres are treated as illustrative rather than statistically representative throughout.

Data Collection Instruments

Data were collected using eleven cadre-specific structured questionnaires administered on KoboToolbox, one for each cadre involved in the CHW data pathway. Every questionnaire followed a common structure. Section A comprised four true-or-false baseline statements about respondents' involvement in emergency-related CHW data work and about the availability of the data system to them. Section B covered emergency experience and common system factors shared across cadres, including the types of emergencies experienced, the geographical setting, the pathway stage most disrupted, the frequency of infrastructure-related reporting delays, the adequacy of emergency-specific training, the clarity of reporting procedures, the effect of community trust and misinformation on data completeness, the factors most undermining continuity, and an overall rating of data quality. Section C comprised six questions tailored to the specific responsibilities of each cadre; for example, Community Health Workers were asked how they submit data, while District Health Information Officers were asked about DHIS2 capacity and interoperability. Section D asked respondents to name a single priority action for the Ministry of Health and Child Care and offered an optional open-ended comment. Because Sections A, B and D used identical wording and response options across all eleven instruments, these responses were pooled into a single cross-cadre dataset for system-wide analysis, while Section C, being cadre-specific by design, was analysed separately for each cadre. All instruments were developed from the study's conceptual domains (Table 1) and piloted prior to full data collection.

Data Management and Analysis

Survey exports from KoboToolbox were cleaned, checked for completeness and analysed descriptively. Pooled Section A, B and D responses were summarised as frequencies and percentages across the full sample and cross-tabulated by health-system level, most notably for the overall data-quality rating. Section C responses were analysed and reported separately for the three largest cadres, Community Health Workers, Facility Nurses in Charge and District Health Information Officers, since together they provided the most statistically robust cadre-specific detail; findings for smaller cadres remain in the underlying dataset but are not reported as standalone percentages given their limited size. Multiple-response items, such as the types of emergencies experienced and the factors most undermining continuity, were summarised as the percentage of respondents selecting each option rather than as a percentage of total selections.

Validity and Reliability

Content and face validity of the survey and companion qualitative instruments were established through review by a panel of experts in CHW programming, monitoring and evaluation, and health emergency management, following recognised content-validity assessment procedures [19]. Instruments were piloted with a small number of informants outside the main sample prior to full data collection and refined accordingly.

Ethical Considerations

The study received approval from the Medical Research Council of Zimbabwe and administrative permission from the Permanent Secretary of the Ministry of Health and Child Care and participating study sites prior to data collection. Written informed consent was obtained from all participants, who were briefed on the purpose, procedures, risks and voluntary nature of participation and who retained the right to withdraw at any stage without consequence. Participant confidentiality was protected through the use of pseudonyms where applicable and secure, access-controlled storage of survey and interview data. Data collectors were trained and briefed, instruments were piloted as described above, and coding and analysis were subject to independent review to ensure alignment between the data, the reported findings and the study's objectives.

Results

This section reports findings from the cross-cadre survey of 142 respondents (140 for most pooled items) who had experience of CHW data work during health emergencies in Zimbabwe between 2018 and 2025. Findings are presented in the order in which the underlying survey sections were administered: sample profile, baseline system resilience, emergency experience and common system factors, cadre-specific highlights for the three largest cadres, and respondents' priority recommendations.

Sample Profile

Community Health Workers, Facility Nurses in Charge and District Health Information Officers together accounted for close to four in five respondents (Table 2, Figure 1), reflecting the frontline focus of the CHW data pathway and of the sampling strategy. Grouped by health-system level, community- and facility-level cadres made up the majority of the sample, with district- and provincial or national-level respondents contributing smaller but analytically important numbers (Figure 2). Most respondents drew on experience from rural settings, with urban, mixed, peri-urban and remote or hard-to-reach settings each represented in smaller numbers (Figure 3).

https://doi.org/10.21522/TIJAR.2014.13.04.Art018

Table 2. Sample Size and Distribution of Survey Respondents by Cadre

Cadre	Respondents (n)	% of Sample
Community Health Worker	48	33.8%
Facility Nurse in Charge	40	28.2%
District Health Information Officer	24	16.9%
Environmental Health Technician	11	7.7%
Provincial Monitoring and Evaluation Officer	5	3.5%
Laboratory Technician	4	2.8%
Community Nurse	4	2.8%
Provincial Laboratory Scientist	2	1.4%
District Nursing Officer	2	1.4%
Provincial Pharmacist	1	0.7%
Deputy Director, Laboratory Services	1	0.7%
Total	142	100%

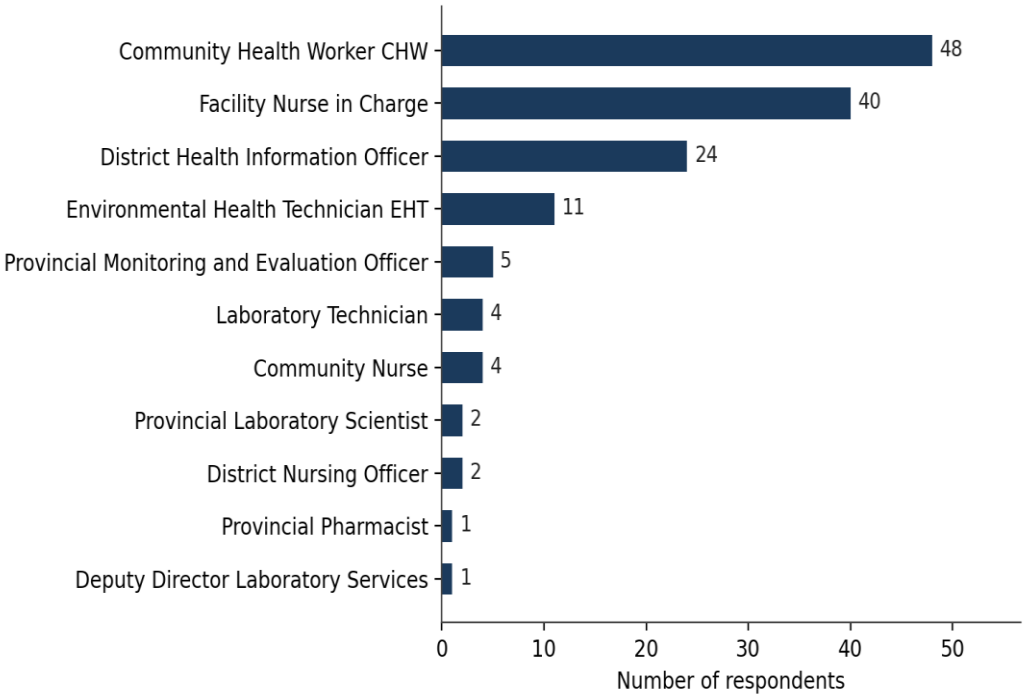


Figure 1. Survey Respondents by cadre (N = 142). Community Health Workers, Facility Nurses in Charge and District Health Information Officers Together Account for Close to Four in Five Respondents

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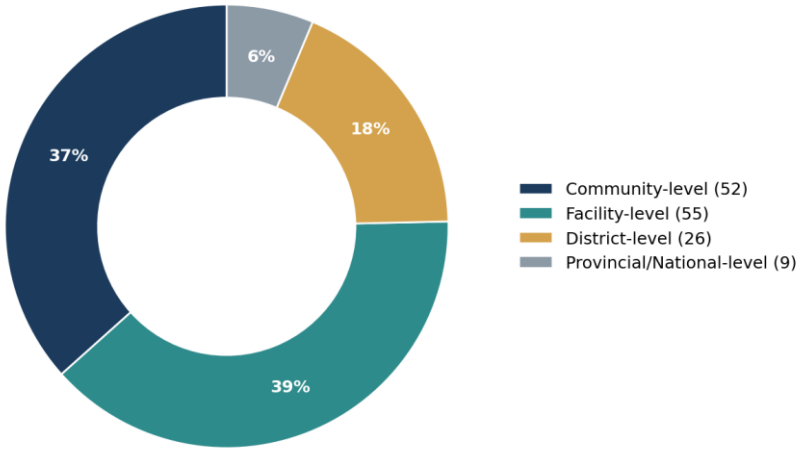


Figure 2. Respondents by Health-System Level. Community- and Facility-Level Cadres Make up the Majority of the Sample, Reflecting the Frontline Focus of the CHW Data Pathway

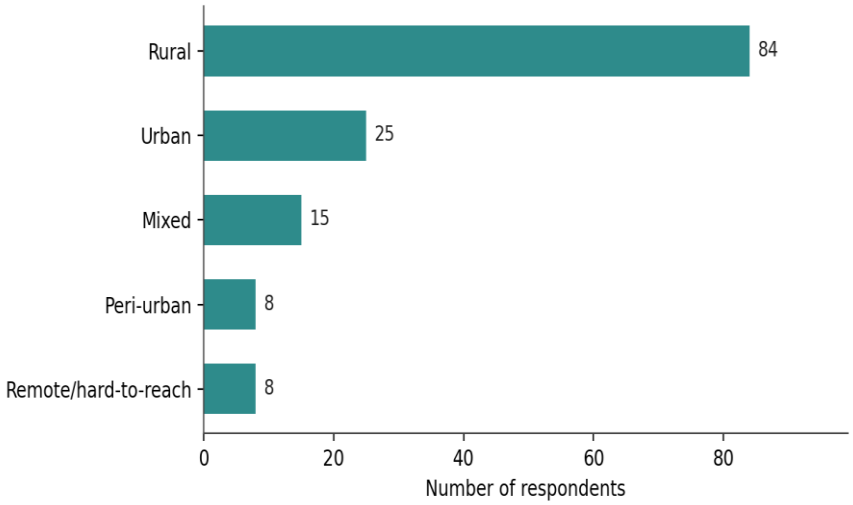


Figure 3. Geographical Setting of Respondents' Primary Emergency Experience (n = 140). Rural Settings Dominate, with Urban, Mixed, Peri-Urban and Remote or Hard-to-Reach Settings Each Represented in Smaller Numbers

Baseline System Resilience

Four true-or-false statements captured respondents' baseline experience of the CHW data system during emergencies (Figure 4). Involvement in emergency-related CHW data work was almost universal, with 95.0% answering true, confirming that the sample was well placed to speak to the topic. A large majority, 89.3%, said their roles were clearly defined, and 75.7% said standard reporting tools remained available. The weakest of the four statements concerned continuity of transmission during a power or connectivity failure: only 67.1% said CHW data could still be transmitted when electricity or internet access failed, meaning close to a third of respondents, 32.9%, hit a hard stop in the flow of data whenever infrastructure failed. This early finding foreshadows a pattern that recurs throughout Section B: connectivity and power resilience emerge as the single largest structural weakness in the CHW data pathway during emergencies.

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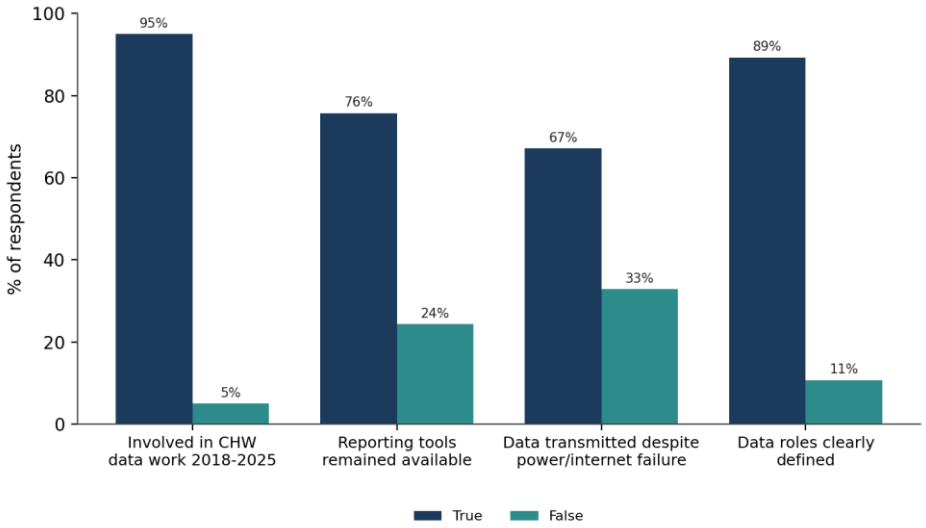


Figure 4. Percentage of Respondents Answering True Versus False to Each Baseline Statement (n approximately 140)

Emergency Experience and Common System Factors

Types of Emergencies Experienced

Respondents could select more than one type of emergency experienced between 2018 and 2025 (Figure 5). COVID-19 dominated respondents' emergency experience, cited by 83.8%, consistent with its scale and duration, and general epidemic or outbreak events were also common at 64.8%. Climate-related emergencies came up less often, with drought or heat events reported by 15.5% and cyclone or flood events by 10.6%, though these still matter a great deal in the provinces most exposed to them.

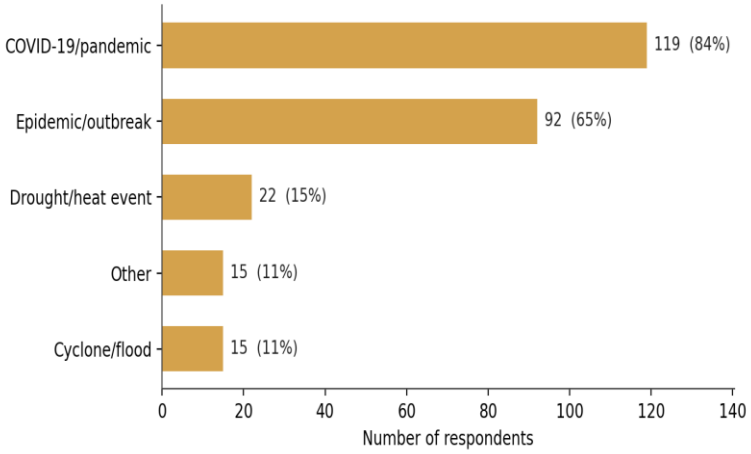


Figure 5. Types of Health Emergencies Experienced (Multiple Responses Allowed, N = 142)

Disruption Along the CHW Data Pathway

Collection was the stage respondents most often cited as a point of disruption, at 30.7%, ahead of feedback and use (23.6%) and transmission (22.1%) (Figure 6). This matters because collection sits at the very start of the pathway, so a failure there works its way through every stage that follows. Verification (16.4%) and aggregation or analysis (7.1%) were flagged far less often, suggesting that once data enter the formal system, the later processing stages hold up reasonably well compared with the initial community-level capture of information.

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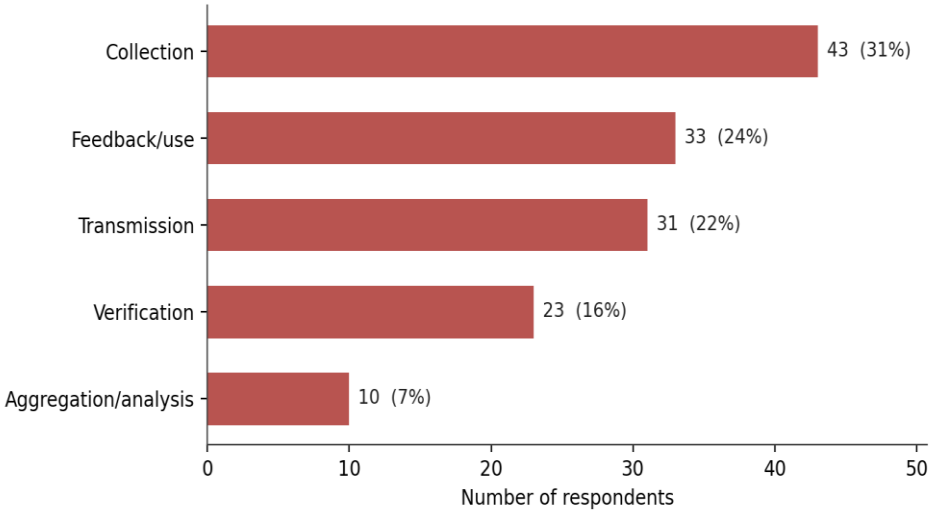


Figure 6. CHW Data Pathway Stage Identified as Most Disrupted (n = 140)

Infrastructure Failures and Reporting Delays

Two-thirds of respondents, 67.9%, said infrastructure failures delayed CHW reporting at least sometimes, and 9.3% said this happened often or always; only 15.0% said such failures never delayed their reporting (Figure 7). This corroborates the baseline finding on transmission continuity and points to infrastructure and connectivity as a recurring problem across the whole system rather than something confined to a few locations.

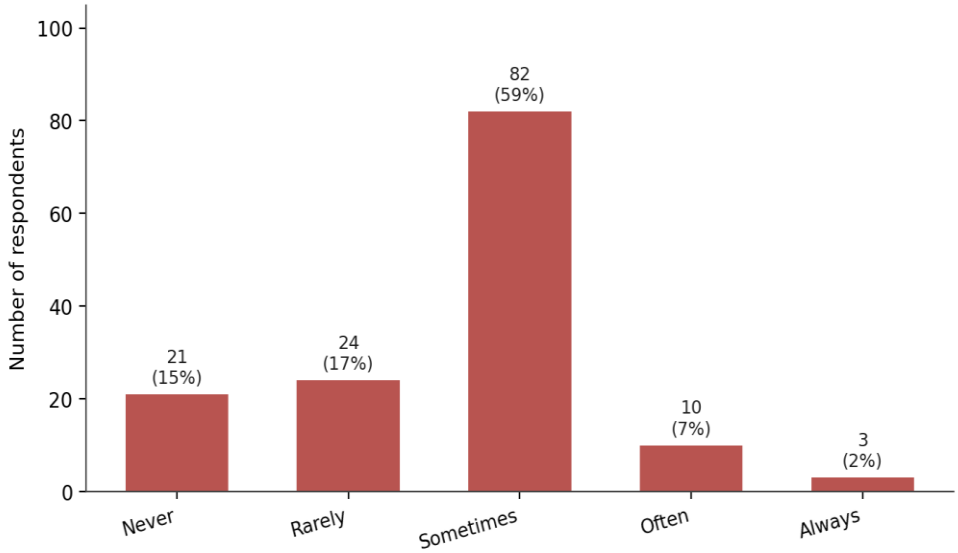


Figure 7. Frequency with Which Infrastructure Failures Delayed CHW Reporting (n = 140)

Adequacy of Emergency-Specific Training

Training stands out as an area needing real strengthening (Figure 8). Just 33.6% of respondents rated emergency-specific training on data tasks as adequate or very adequate, nearly half, 47.1%, rated it only fair, and 19.3% rated it inadequate or very inadequate. Because data collection was separately identified as the most disrupted pathway stage, it is plausible that under-investment in training for frontline data tasks contributes to that disruption.

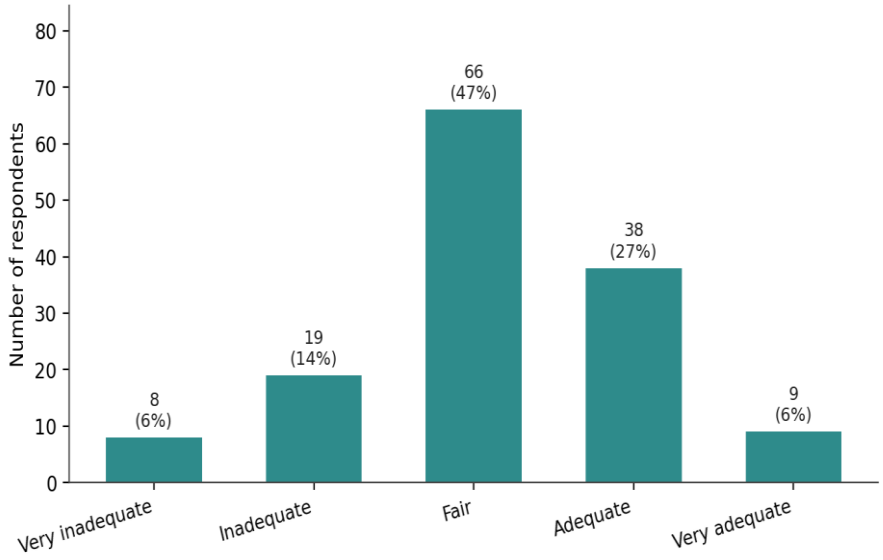


Figure 8. Adequacy of Emergency-Specific Training on Data Tasks (n = 140)

Clarity of Reporting Procedures and Accountability

Procedural clarity fared somewhat better than training (Figure 9). Just over half of respondents, 53.6%, found emergency reporting procedures and accountability lines clear or very clear, compared with 9.3% who found them unclear or very unclear. Just over a third, 37.1%, rated clarity as only fair, suggesting there is still room to sharpen and standardise emergency standard operating procedures even though a basic structure is already in place.

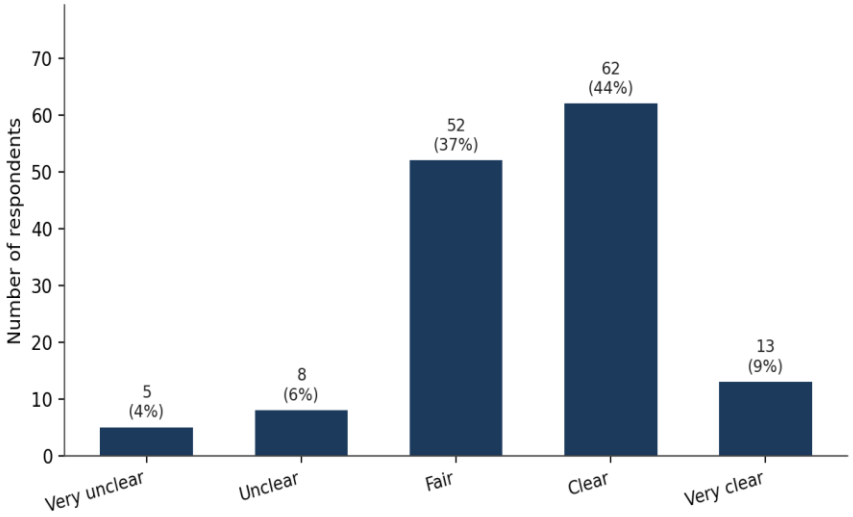


Figure 9. Clarity of Emergency Reporting Procedures and Accountability Lines (n = 140)

Community Trust, Stigma and Misinformation

Nearly half of respondents, 47.9%, said community trust, stigma, language or misinformation affected data completeness moderately, substantially or extremely, while 17.1% said it had no effect at all (Figure 10). This underlines that technical and infrastructural fixes alone will not resolve data-completeness gaps, and that community engagement and risk-communication strategies also matter a great deal to data quality during emergencies.

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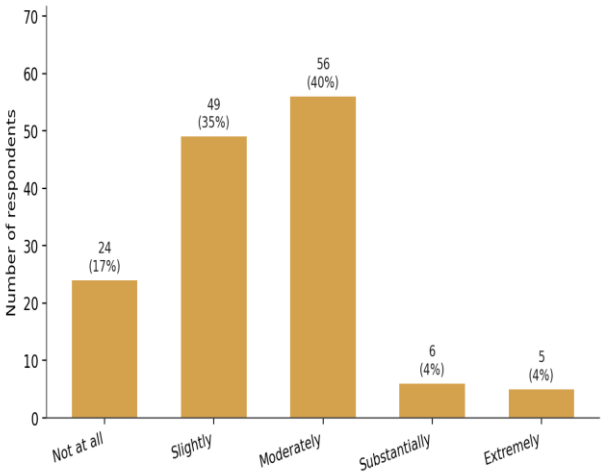


Figure 10. Effect of Community Trust, Stigma, Language or Misinformation on Data Completeness (n = 140)

Factors Most Undermining Continuity

Respondents selected up to three factors that most undermined the continuity of CHW data systems during emergencies (Figure 11). Tools and devices (67.6%) and power and connectivity (58.5%) were by far the most frequently selected factors, echoing the infrastructure findings already described. Workload and staffing (45.1%) and skills (40.1%) followed, while sociocultural barriers (33.8%) and governance or coordination (12.7%) were selected less often. Taken together, these results point to hardware and workforce capacity as the main constraint, with governance and coordination a smaller, though still relevant, bottleneck.

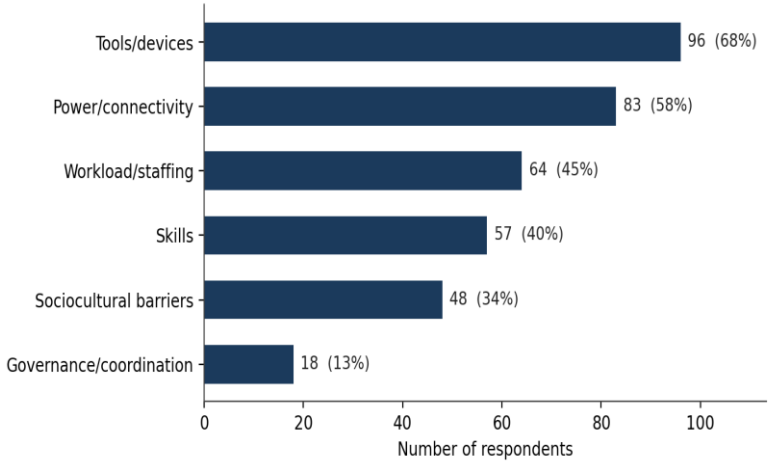


Figure 11. Factors Most Frequently Selected, Among up to Three, as Undermining Continuity of CHW Data Systems (N = 142)

Overall Rating of Data Timeliness and Quality

Just under half of respondents, 48.6%, rated overall CHW data timeliness and quality during emergencies as good or very good, 41.4% rated it fair, and 10.0% rated it poor or very poor (Figure 12). This is a cautiously positive picture: most respondents see the system as functional, but the large fair rating alongside a meaningful poor or very poor minority indicates substantial room for improvement.

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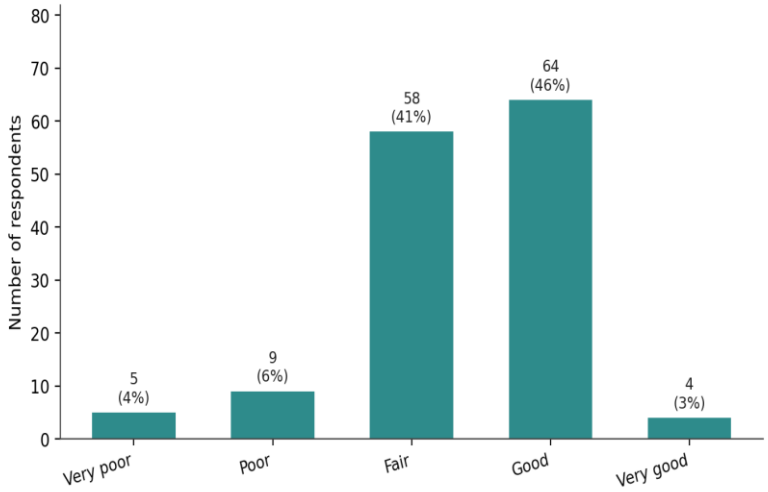


Figure 12. Overall Rating of CHW Data Timeliness and Quality During Emergencies (n = 140)

Rating by Health-System Level

Perceptions of data quality improved further up the health system (Figure 13). Sixty-seven percent of provincial and national-level respondents rated data quality as good, compared with 50% at district level, 45% at facility level and 40% at community level. Community-level respondents, who sit closest to the point of data capture and are most exposed to the connectivity, device and workload pressures already described, reported the least favourable picture, including the highest share of very poor ratings of the four groups, at 6%, compared with 4% at district level, 2% at facility level and none at provincial or national level. This gradient suggests that problems visible to frontline workers may not be fully appreciated further up the system, supporting the case for weighing frontline perceptions alongside those from higher levels rather than treating any single level's assessment as the whole picture.

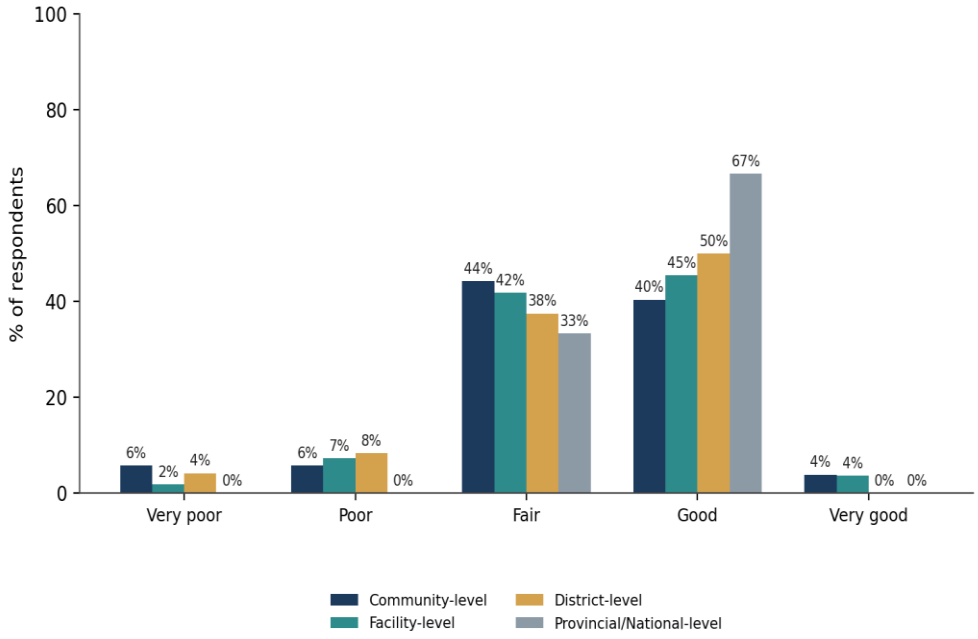


Figure 13. Overall Data-Quality Rating by Health-System Level (Percentage Within Level)

Role-Specific Findings for the Three Largest Cadres

Section C questions were tailored to each cadre's specific responsibilities within the CHW data pathway and were therefore not pooled across cadres. This section summarises the leading responses for the three largest cadres in the sample: Community Health Workers (48 respondents), Facility Nurses in Charge (40 respondents) and District Health Information Officers (24 respondents).

Community Health Workers

Community Health Workers sit at the point of first data capture, and their responses highlight practical, resourcing-level barriers rather than conceptual or technical ones (Table 3). A lack of tools or forms (44%) and movement restrictions (38%) were the leading reasons recording was incomplete, and paper submission to facilities (50%) remained the dominant reporting channel, alongside informal channels such as phone calls, SMS (29%) and WhatsApp (17%). Stigma or fear (25%) and misinformation (25%) were the community factors most often identified as affecting reporting. On a more encouraging note, most CHWs reported at least moderate confidence that their data were used for local action, and facility feedback on errors or missing data was reasonably frequent, suggesting the supervision loop was partly functioning even where tools remained scarce. The reliance on paper and informal channels, at 46% combined for phone, SMS and WhatsApp, reflects the connectivity gaps identified system-wide, and the lack of tools and forms confirms, from the frontline perspective, why collection emerged as the most disrupted pathway stage overall.

Table 3. Role-Specific Survey Findings, Community Health Workers (n = 48)

Question	Leading Response(s)
What most often prevents complete recording of household or client data?	No tools or forms (44%); movement restrictions (38%)
How do you usually submit community data?	Paper to facility (50%); phone call or SMS (29%); WhatsApp (17%)
How often does the facility give feedback on errors or missing data?	Sometimes (50%); always (25%); rarely (10%)
Which community factor most affects reporting?	Stigma or fear (25%); misinformation (25%); low trust (17%)
What support would most improve emergency reporting?	Phone or device (29%); refresher training (29%); airtime or data bundles (27%)
Confidence that reported data are used for local action	Very confident (33%); moderately confident (33%); completely confident (31%)

Facility Nurses in Charge

Facility Nurses in Charge sit at the interface between community-level collection and the formal health information system (Table 4). Thirty-two percent identified CHW collection as the largest bottleneck in community data flow, ahead of verification (22%) and receipt at facility (20%), corroborating the CHW-level finding that collection is the weakest link. Workload (35%) and staff shortages (20%), not only connectivity (25%), limited timely verification. Reconciliation of CHW reports with facility data was reported as consistently strong, at 82% always or often, indicating that once data reach the facility, quality-control processes function reasonably well. Informal

channels, WhatsApp or SMS (52%) and phone (32%), dominated urgent-signal escalation over formal paper forms (10%), at 84% combined, again pointing to adaptive, informal workarounds rather than fully resourced formal channels.

Table 4. Role-Specific Survey Findings, Facility Nurses in Charge (n = 40)

Question	Leading Response(s)
Where is the largest bottleneck in community data flow?	CHW collection (32%); verification (22%); receipt at facility (20%)
How often are CHW reports reconciled with facility data?	Always (70%); often (12%)
What most limits timely verification?	Workload (35%); connectivity (25%); staff shortages (20%)
How are urgent community signals most commonly escalated?	WhatsApp or SMS (52%); phone (32%); paper form (10%)
Which preparedness measure should be prioritised?	Data bundles (32%); staff cross-training (22%); emergency tools (20%)
How often do community data change facility decisions?	Sometimes (50%); always (20%); often (12%)

District Health Information Officers

District Health Information Officers manage the technical backbone of the data system, aggregation, validation and interoperability (Table 5). Connectivity (42%) was again identified as the leading technical failure affecting reporting, ahead of server or platform downtime (29%), and validation (50%) was the data-processing step requiring the most correction, consistent with data-quality issues originating upstream at the point of collection. A quarter of officers received emergency reports outside the official system often or sometimes, pointing to informal parallel reporting that formal systems do not fully capture. Most, 62%, rated DHIS2 and system capacity as adequate for emergency community data, suggesting the core information system itself is broadly fit for purpose, with the bottleneck lying more in what reaches it, through connectivity, offline capture and manual transfer, than in the platform itself. Offline capture (42%) and backup power or server capacity (33%) were identified as the most important safeguards, reinforcing the infrastructure priority identified across the whole system.

Table 5. Role-Specific Survey Findings, District Health Information Officers (n = 24)

Question	Leading Response(s)
Which technical failure most affects CHW reporting?	Connectivity (42%); server or platform downtime (29%); user access (12%)
Which data-processing step requires most correction?	Validation (50%); completeness checks (21%); aggregation (8%)
How often are emergency reports received outside the official system?	Never (25%); rarely (25%); sometimes (25%)
What is the main interoperability problem?	Manual transfer (25%); non-standard indicators (25%); duplicate platforms (21%)

Which safeguard is most important?	Offline capture (42%); backup server or powe (33%); routine backup (12%)
How adequate is DHIS2 or system capacity for emergency community data?	Adequate (62%); fair (17%); inadequate (12%)

Priority Recommendations from Respondents

All respondents were asked to identify the single action the Ministry of Health and Child Care should prioritise to make CHW data systems more resilient during future emergencies (Figure 14). Investment in infrastructure and technology was the most frequently chosen priority, at 32.9%, closely followed by workforce and training strengthening at 30.0%; together these two options accounted for almost two-thirds of all responses. Community engagement, at 20.0%, was the third most common priority, consistent with the sizeable share of respondents who reported that community trust, stigma and misinformation affect data completeness. Supervision and feedback (13.6%) and, less often, governance and standard operating procedures (2.1%) and interoperability (1.4%) made up the remaining responses. This ordering aligns closely with the factors respondents identified as undermining continuity, where tools and devices and power and connectivity ranked highest, together suggesting that infrastructure and workforce capacity, rather than governance or system design, are what respondents themselves want addressed first.

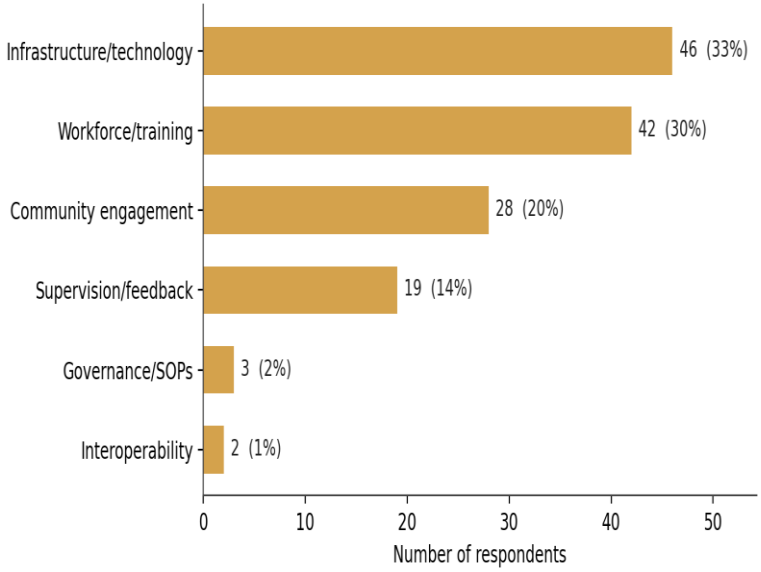


Figure 14. Priority Action Recommended for the Ministry of Health and Child Care to Strengthen CHW Data System Resilience (n = 140).

Discussion

A growing body of international literature documents the vulnerability of community-based health information systems during crises, and the present survey findings sit squarely within that pattern while adding Zimbabwe-specific, cross-cadre quantification. Interrupted time series analysis of routine data from twenty-seven districts across four sub-Saharan African countries found that the continuity of community-based care during COVID-19 depended substantially on whether CHWs had been adequately remunerated, supplied and supervised before the pandemic began, with better-supported cadres able to sustain

reporting where less-supported ones could not [8]. This is consistent with the present finding that only 67.1% of respondents could still transmit CHW data when electricity or internet access failed, and that tools and devices (67.6%) and power and connectivity (58.5%) were the two factors most frequently blamed for undermining continuity. Complementary work across the Democratic Republic of Congo, Nigeria, Senegal and Uganda found that CHWs played a central role in COVID-19 case detection, contact tracing and risk communication, but that connectivity limitations, inadequate data collection tools and insufficient integration into national reporting systems constrained the reliability of the data they generated [9], a pattern mirrored almost exactly by Zimbabwean CHWs' own account of paper-based submission (50%) and informal phone, SMS and WhatsApp channels (46% combined) substituting for more robust digital tools. Across the region more broadly, the World Health Organization has reported that a large majority of countries experienced disruption to essential health services during the pandemic, with community-level reporting systems among the functions most affected [20].

Digitisation has been positioned as a central strategy for improving the timeliness and quality of community health data, but the evidence on implementation is mixed, and the present survey helps explain why. In Ethiopia, a phenomenological study of the electronic community health information system found that health-worker education level, resistance to new tools, unreliable electricity and network infrastructure, interoperability problems between parallel systems, weak coordination among stakeholders, and limited trust in shared platforms each independently undermined effective use of the system [1]. A subsequent implementation-science study using the CFIR-ERIC framework in Ethiopia's East Shewa zone similarly identified limited network connectivity, low digital literacy, frequent power outages and device-maintenance difficulties as recurring barriers, while identifying leadership engagement, clear guidelines, interoperability design and technical support as facilitators [4]. The Zimbabwean survey data extend this picture with a pathway-stage diagnosis: rather than digitisation failing uniformly, it is community-level collection specifically, chosen by 30.7% of respondents as the most disrupted stage, that bears the brunt of infrastructural and workforce constraints, while District Health Information Officers rated the core DHIS2 platform itself as largely adequate (62%). A broader review of digital health interventions for health-system strengthening across Ethiopia, Ghana and Zimbabwe found that fragmentation across parallel platforms, including Zimbabwe's own Impilo electronic health record system, continues to constrain the extent to which community-generated data can be integrated into a single, interoperable national architecture, despite the platform's expanding functionality [10], a finding echoed in the present survey by District Health Information Officers' identification of manual transfer, non-standard indicators and duplicate platforms as leading interoperability problems.

Regional analyses of the broader African digital health landscape reinforce these findings, noting that infrastructure gaps, particularly unreliable electricity and internet connectivity in rural areas, remain the central technical constraint on cloud-based and mobile reporting systems, even as continental initiatives promote common data-exchange standards to improve interoperability across countries [21]. For Zimbabwe specifically, the Global Fund's 2025 digital health case study highlights that inconsistent power and internet access at facility and community level directly undermines the country's capacity for digitised surveillance, patient-centred care and supply-chain data management, with national power shortages estimated to cost the economy the equivalent of 6.1 percent of gross domestic

product annually [11]. The present survey provides direct workforce-level evidence for this claim: two-thirds of respondents, 67.9%, reported that infrastructure failures delayed CHW reporting at least sometimes, and infrastructure investment was respondents' own top priority for the Ministry of Health and Child Care, at 32.9%.

Zimbabwe's own emergency history provides the most directly relevant evidence base for this study, and the survey sample's emergency experience, dominated by COVID-19 (83.8%) and general epidemic or outbreak events (64.8%), reflects that history closely. Descriptive epidemiological analysis of the 2018-2019 cholera outbreak found that effective control depended on a functioning, multisectoral surveillance system capable of rapid case detection and response coordination, implicitly underscoring the consequences of gaps in community-level reporting [5]. The 2023 Chegutu cholera outbreak, which spread to seventeen hotspot districts across all ten provinces and resulted in almost 5,000 confirmed and suspected cases, prompted policy recommendations emphasising the need for improved risk communication, stakeholder engagement, data standardisation and capacity-building to strengthen future outbreak surveillance and response [12]. Response reporting from the International Federation of Red Cross and Red Crescent Societies similarly documented that the rapid, multi-province spread of the 2023 outbreak strained existing surveillance and coordination systems, reinforcing the case for stronger community-level data architecture ahead of future outbreaks [13].

During the COVID-19 pandemic, Zimbabwe's Ministry of Health and Child Care, in collaboration with the World Health Organization's Universal Health Coverage Partnership and other global health initiative partners, worked to establish a real-time, weekly routine monitoring system anchored in the District Health Information System, explicitly in order to sustain data-driven decisions on the continuity of essential services [7]. The very necessity of this intervention indicates that pre-existing community and facility reporting mechanisms had not been resilient enough, on their own, to withstand the disruption caused by the pandemic, a conclusion the present survey supports directly: just 33.6% of respondents rated their emergency-specific training as adequate or better. Zimbabwe's establishment, from 2024 onward, of a network of Public Health Emergency Operations Centres, equipped to serve as multisectoral command and coordination hubs following recurrent cholera outbreaks, Cyclone Idai and the COVID-19 pandemic, reflects a policy-level acknowledgement of the need for stronger, better-coordinated emergency data and coordination infrastructure [3].

Beyond infrastructure and technology, the literature points consistently to workforce and governance factors as key determinants of community health data system performance. Weak supervision, limited feedback loops between community-level reporting and higher-level decision-making, and insufficient coordination among the multiple actors involved in emergency response have each been identified as constraints on the effective use of community-generated data, even where the underlying data are collected [1, 4]. The survey data qualify this picture usefully: governance and coordination were selected by only 12.7% of respondents as a factor undermining continuity, well behind tools and devices and power and connectivity, suggesting that in the Zimbabwean case the more visible, tangible resourcing gaps currently outweigh governance and coordination as the binding constraint, even though procedural clarity itself was rated only moderately favourably (53.6% clear or very clear). Sociocultural factors, including community trust in CHWs, language diversity, and stigma associated with certain conditions, further shape both the willingness of

community members to report and engage during emergencies and the completeness of the resulting data [3], a pattern the survey confirms directly: 47.9% of respondents said community trust, stigma or misinformation affected data completeness to at least a moderate degree, and Community Health Workers themselves identified stigma, fear and misinformation as the community factors most affecting their reporting. Taken together, this evidence suggests that Zimbabwe's recurrent difficulty in sustaining reliable CHW data systems during emergencies is not attributable to any single factor, but rather to the interaction of infrastructural, institutional, workforce and sociocultural conditions, a premise that underpins both the conceptual framework guiding this study and the pattern of findings it has produced.

A further contribution of the survey is its demonstration that vulnerability is not evenly distributed across the health system. Data-quality ratings improved steadily from community level (40% good or very good) through facility (45%) and district (50%) to provincial or national level (67%), and community-level respondents also reported the highest share of very poor ratings. This gradient is consistent with, and adds quantitative precision to, the broader observation in the literature that frontline perspectives are often under-represented in system assessments conducted from higher administrative levels. It suggests that national-level assessments of CHW data system performance, if based only on facility, district or provincial informants, risk understating the severity of problems as they are actually experienced at the point of data capture.

While the reviewed literature establishes, with reasonable consistency, that community health information systems across sub-Saharan Africa are vulnerable during health emergencies, and while Zimbabwe-specific evidence documents the consequences of this vulnerability across successive cholera outbreaks and the COVID-19 pandemic, comparatively little of the existing scholarship integrates these strands into a single, contextually grounded, quantified account of why CHW data systems specifically falter during emergencies in Zimbabwe. This study helps to close that gap by generating primary, cross-cadre survey evidence directly from the CHWs, nurses, technicians, information officers and managers who have operated these systems through recent emergencies, complementing the parallel qualitative strand of the wider doctoral project.

Taken together, the findings suggest that technical investment alone is unlikely to produce a resilient community health data system. Electricity, connectivity and interoperability are necessary, but their value depends on workforce capability, clear governance, supervision, feedback and community trust, all of which the survey shows to be present but incomplete: reporting tools are broadly available (75.7%), the core DHIS2 platform is broadly rated adequate (62%), and facility-level reconciliation of CHW reports is strong (82% always or often), yet training remains under-resourced and community-level experience of the system remains the least favourable of any group. The pattern that emerges is one of a system whose technical backbone is comparatively sound but whose frontline, community-level layer is where investment is most urgently needed.

Implications for Policy and Practice

The survey findings indicate that emergency preparedness should embed community data continuity within routine system strengthening, rather than treating it as a separate, crisis-only concern. Priority actions, informed directly by respondents' own stated priorities and by the factors they identified as undermining continuity, include expanding offline-capable and interoperable reporting tools for CHWs, providing devices and airtime or data allowances to frontline workers, developing a

structured and recurring emergency-specific training curriculum with particular emphasis on data-collection tasks, pairing infrastructure and training investment with targeted community engagement and risk-communication strategies, and formally recognising and integrating the WhatsApp, SMS and phone-based channels that facility nurses and CHWs already rely on for urgent escalation. District-level safeguards such as offline capture and backup power or server capacity, prioritised by District Health Information Officers, should be extended alongside efforts to standardise indicators and reduce manual transfer and duplicate-platform problems. Public Health Emergency Operations Centres should receive defined community-level data streams and should communicate actionable feedback back to districts and frontline cadres, and system reviews should treat community- and facility-level perceptions as a leading indicator, given that these levels report the least favourable data-quality ratings and sit closest to the point where problems originate.

Study Limitations

Several limitations should be considered when interpreting these findings. The survey sample, while substantial at 142 respondents across eleven cadres, was not evenly distributed: Community Health Workers, Facility Nurses in Charge and District Health Information Officers accounted for 79% of respondents, while several provincial and specialist cadres had only one or two respondents, so findings for these small cadres are indicative only and are not reported as standalone percentages. The sample was also geographically concentrated, with Mashonaland East and Midlands provinces together accounting for 70% of respondents, so findings may not generalise evenly to all provinces. Responses were self-reported and retrospective, covering emergencies from 2018 to 2025, and are therefore subject to recall and social-desirability bias, particularly for respondents describing more than one past emergency and for questions touching on organisational performance. Because Section C questions differed by cadre by design, direct statistical comparison across cadres on role-specific items was limited, and only the three largest cadres are reported individually here. Two respondents did not complete the substantive sections beyond the consent stage, so pooled percentages for these sections are calculated out of 140 rather than the full 142. As a purposive, non-probability sample, the survey supports descriptive, context-specific conclusions rather than nationally representative statistical inference; the parallel qualitative strand of the wider study, and future work extending the survey to additional provinces and cadres, will help to test the transferability of these findings.

Conclusion

Reliable community-level information is indispensable during health emergencies, yet the conditions that increase demand for rapid data can simultaneously weaken the systems that produce it. This cross-cadre survey of 142 respondents across eleven cadres of Zimbabwe's health workforce shows that the country's community health data infrastructure is engaged, broadly structured and, at its technical core, judged largely adequate, yet it remains constrained precisely at the point of community-level collection, where tools, connectivity, power and training are least secure. What respondents identify as undermining continuity of their data systems lines up closely with what they themselves recommend the Ministry of Health and Child Care prioritise: infrastructure and connectivity investment, followed by workforce training, community engagement and stronger supervision and feedback. Addressing these priorities in a sequenced, community-facing way, rather than through technical investment alone, offers a practical route toward more resilient, emergency-responsive community

health information systems, and the findings reported here, together with the parallel qualitative evidence being generated by the wider study, are intended to support that agenda within Zimbabwe's 2026-2030 National Health Strategy and its emerging Public Health Emergency Operations Centre architecture.

Conflict of Interest

The author declares no financial or commercial conflict of interest. The author's professional role within the Ministry of Health and Child Care creates a potential positionality consideration, which was managed through reflexive documentation, transparent sampling and independent review of the analysis.

Ethical Approval

Ethical approval was obtained from the Medical Research Council of Zimbabwe, together with administrative permission from the Ministry of Health and Child Care and participating study sites, before data collection. No participant recruitment or data collection began before all required approvals had been obtained.

Author Contributions

Tafadzwa Dzamara conceived the study, developed the protocol and survey instruments, led data collection through KoboToolbox, conducted the analysis, undertook the literature synthesis, and prepared the manuscript.

Acknowledgements

The author acknowledges the 142 survey respondents who gave their time to share their experience of CHW data systems during health emergencies, and the academic and professional colleagues who have supported the development of the research concept.

Data Availability

The datasets generated and analysed during the current study are not publicly available due to the terms of the ethical approval granted by the Medical Research Council of Zimbabwe and the conditions of administrative permission from the Ministry of Health and Child Care, which restrict onward sharing of respondent-level data. De-identified data are available from the corresponding author on reasonable request, subject to permission from the Medical Research Council of Zimbabwe and the Ministry of Health and Child Care.

Funding

This research was self-funded by the author. No external grant, sponsorship or institutional funding was received for the design, conduct, analysis or reporting of this study.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art019

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Strategic Management and Cybersecurity: A Literature Review on Enhancing Organisational Resilience in the Digital Era for Small to Medium-Sized Businesses

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Cite this article as: Shurland CP. Strategic management and cybersecurity: A literature review on enhancing organisational resilience in the digital era for small to medium-sized businesses. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art019**

Received: 23.08.2026
Accepted: 02.10.2026
Published: 30.10.2026

Article Type: Original Research

Abstract *This review examines the theoretical and empirical literature at the intersection of strategic management and cybersecurity, and how organisations can strategically manage cybersecurity to strengthen their resilience in the digital era. The review synthesises eight components of the literature, including the theoretical foundations of strategic management; the role of strategic management in cybersecurity; cybersecurity challenges in the digital era; emerging technologies; cybersecurity incidents and business continuity; leadership and organisational culture; building organisational resilience; and best-practice frameworks. The literature consistently indicates that cyber resilience is not achieved through isolated information technology (IT) controls but through integrated strategic management that connects cyber risk, operational priorities, and business continuity. Gaps remain in the contextual literature on developing economies, where empirical evidence on the relationship between strategic management and cybersecurity remains limited.*

Keywords *Cybersecurity, Cyber Resilience, Governance, Organisational Resilience, SMEs, Strategic Management.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art019

Introduction

This study examines how organisations can integrate cybersecurity and strategic management to strengthen their resilience in the digital era. It highlights the rapid increase in cybersecurity threats that many organisations face due to advances in digital technology. These threats affect not only its operations but reputation and financial stability. This paper highlights the importance of enhancing organisational resilience against these cyber threats with a focus on how it can be applied to the SMEs in Guyana. The acceleration of this digital transformation has fundamentally changed how organisations operate and deliver value.

Cyber threats have evolved from traditional threats due to the rapid increase in technology and complex digital ecosystems. Consequently, SMEs are shifting from traditional practices of prevention to cyber resilience, emphasizing the ability to anticipate, withstand, recover from, and adapt to cyber disruptions. This evolution highlights the need to integrate cybersecurity into strategic management, to ensure alignment between technological innovation, governance, and business continuity objectives [1].

Objectives

The objective of the study is to investigate cybersecurity and strategic management, how they can be integrated to improve the resilience of businesses in Guyana against cyber threats. The primary objectives of the research are:

1. To investigate the role of strategic management in addressing cybersecurity challenges.
2. To identify strategic approaches and best practices businesses can adopt to enhance cybersecurity resilience.
3. To examine the impact of cybersecurity threats on business performance and resilience.
4. To analyse the benefits and challenges of integrating cybersecurity into strategic management processes.
5. To propose possible recommendations for SMEs to develop and implement cybersecurity strategies.

Research Questions

"How can strategically managing cybersecurity enhance the resilience of businesses in Guyana towards cyber threats in the digital era?"

Justification

The businesses in Guyana are growing exponentially and moving towards the digital era just as the rest of the world, and therefore, the reliance on technology is important. In view of this, businesses are exposed to various types of cyber-attacks, thus the need for this research.

This research highlights valuable insights into the following areas:

How to effectively enhance cybersecurity to protect against growing threats.

How the gap between strategic management and cybersecurity can be bridged to foster coordination across all departments of the business, thus ensuring resilience, sustainability and competitive advantage.

As the Guyana's economy grows, developing businesses will require top-tier digital infrastructure in numerous sectors, and cybersecurity measures must align with the corporate goal to not leave businesses vulnerable or susceptible to cyber threats.

The Government and Corporate leaders in Guyana can find practical implications from this research, which identifies best practices for the integration of the two disciplines. The recommendations will be actionable and can be implemented across sectors in the Country. On the other hand, policymakers with insights to create, amend and propose a relevant regulatory framework, were recommended in the results article on the study of SMEs in Georgetown, Guyana (which is under review).

More importantly, this paper will guide and support directors, shareholders and business

owners on how to anticipate, prepare, respond, and recover from cyberattacks by providing best practices, practical and actionable recommendations, all together building their resilience.

Limitations

There was limited availability of data as the data and empirical evidence were compiled to support the basis of the research, noting its sensitive nature to cybersecurity and management strategies on cyber incidents. The research could not find telling data for SMEs located in Guyana. The depth and breadth of the data collected relating to actual cyber incidents and the effectiveness of the implemented strategies will be affected when tailored to Guyana.

Hypotheses

It is the assumption that integrating strategic management with cybersecurity measures directly influences organisational resilience against digital threats.

As such, there is a significant gap revolving on the integration of the two disciplines in order to build business resilience among SMEs.

Materials and Methods

A mixed method research design was adopted to include a quantitative component to measure patterns, relationships and statistical associations among strategic management practices, cybersecurity integration and organisational resilience. The qualitative component explored the experiences and perceptions of cybersecurity practitioners and national stakeholders.

Inclusion – Exclusion Criteria

The literature reviewed was selected and included if they addressed the relationship between strategic management and cybersecurity, or cybersecurity's contribution to organisational resilience and business continuity. The literature being peer-reviewed or otherwise authoritative was included; and was relevant to small and medium-sized enterprises (SMEs). The sources that were peer-reviewed journal articles were spread across various International Journal of Business, Economic, Financial Reviews and Information Systems along with conference papers, scholarly textbook, a doctoral dissertation, ISO/IEC 27001:2022, Guyana's Cyber Crime Act 2018 and Data Protection Act 2023, and reputable trade publications. Sources were excluded if not peer-reviewed or unavailable in full text, English, treated cybersecurity purely as a technical function with no strategic dimension, or fell outside the review's thematic scope. These criteria ensured the information was relevant, methodologically sound evidence base and credible.

State of the Art

The current state highlights strategic management and cybersecurity as a vital component for building cyber resilience in business in the digital era while most still view cybersecurity as a technical function only. However, as businesses are facing frequent and complex cyber challenges, this makes cybersecurity a strategic priority rather than a technical function. While digital transformation is rapidly accelerating, cybersecurity maturity still remains an emerging concern. This creates a critical need for businesses in to align cybersecurity with strategic management processes**.**

Further, several articles/journals reviewed, highlighted relationships with digital transformation, cybersecurity, its framework and strategic management only in SMEs. The study focused a range of articles across various sectors, including financial services, government and public services, manufacturing, healthcare, education and other activities. This provided an appropriate context for examining how organisations that depend on digital technologies manage cybersecurity and organisational resilience.

There is limited research on how the integration of both can enhance organisational resilience especially in Guyana since, as a country, they are way behind on technological advancement. This gap involving the strategic role of cybersecurity in strengthening business resilience against cyber challenges/threats in Guyana, post-pandemic was addressed in the results article on the study of SMEs in Georgetown (under review). The acceleration of digital adoption in Guyana, its oil-driven economic modernisation, and an emerging national cybersecurity governance architecture led by the National Data Management Authority (NDMA), the national Computer Incident Response Team (CIRT.GY), the Data Protection Act 2023 and the Cyber Crime Act 2018 were addressed.

Theoretical Perspective

The study adopts a mixed theoretical perspective, combining positivism and interpretivism, to comprehensively address the research question. The positivist perspective supports the quantitative aspect of the study to examine the measures of strategic management process integrated into cybersecurity to enhance organisational resilience. The following theories included, supports the research variables and hypotheses;

1. Resource-Based View
2. Dynamic Capabilities Theory
3. Risk Management Theory
4. Organisational Resilience Concept
5. Strategic Management Theory

Conceptual Framework: Literature Review

Theoretical Foundation of Strategic Management

Strategic Management's foundation encompasses many fundamental business concepts and involves formulating, implementing, and evaluating strategies to achieve an organisation's vision and mission. Each concept comprises processes, frameworks, and theories to guide businesses in making decisions aligned with their vision and mission, thereby optimising their competitive advantage. According to the authors [2], strategy competes differently to obtain and maintain a competitive advantage in the respective industry or business sector. They argued that ‘Company strategy is the actions managers take to outperform their competitors and achieve superior profitability.

There are several frameworks developed by scholars in the field that help to craft the foundation of Strategic Management. Classical Management Theories, developed by thinkers such as Fredrick Taylor and Henri Fayol, primarily focused on operational efficiency and organisational structure, outlined as fundamental groundwork for future thinkers in the field, and emphasised the importance of planning and control. Industrial Organisation Economics was introduced by Michael Porter, who promoted the concepts of Porter's Five Forces and the Competitive Advantage framework, highlighting the competitive forces shaping an industry and how firms can position themselves strategically to gain a competitive advantage. The Resource-Based View, introduced by Jay Barney and others, focuses primarily on internal resources and capabilities instead of external industry factors, surrounding the firm's unique resources, namely its brand, human capital, technology, and others, to provide a sustainable competitive advantage. Institutional theorists DiMaggio and Powell posited that institutions and societal norms have a role in shaping organisational strategies.

Strategic Management encompasses concepts such as Strategy Formulation, Implementation and Control. Strategy Formulation involves the identification of a firm's mission, vision, and goals, analysing its internal and external environment, and formulating strategies to achieve those goals; SWOT, PESTEL, and scenario planning are used during strategy formulation. Strategy Implementation includes allocating resources

and designing the organisational structure and all processes and systems to support the firm's strategies. Strategic control involves monitoring and adjusting strategies to ensure they remain relevant and practical; strategic control mechanisms help firms stay on course with strategy formulation and adapt to changing circumstances faced by the business.

Moreover, strategic management has evolved in the digital era to address the challenges posed by rapidly advancing technology and the digital landscape. Some contemporary trends include (1) Digital Transformation, where many firms leverage digital technologies to streamline operations, enhance customer experiences, and create new business models, and (2) Cybersecurity Integration, as this research suggests, integrating cybersecurity into strategic management is vital and protecting digital assets and data is essential for businesses in today's interconnected world. Strategic management is a multifaceted field that draws on a rich theoretical foundation; it has continued to evolve by adapting to the challenges and opportunities presented in the digital era. Therefore, this research into the intersection of Strategic Management and Cybersecurity is particularly timely, as businesses must navigate the complex terrain of digital threats while pursuing their strategic goals.

The Role of Strategic Management in Cybersecurity

In this evolving digital era, businesses face an increasing array of cyber threats that can undermine its operations, reputation, and, in some instances, existence. However, for companies to protect their assets effectively, the concept of integrating strategic management into cybersecurity processes emerged. Cybersecurity has become increasingly a concern for many firms worldwide, and Guyana is no exception.

The Role of Strategic Management in Cybersecurity covers two broad spectrums, namely Organisational Cybersecurity and Broader Cybersecurity Policy and Planning. At the Organisational level, companies are faced with cybersecurity risks, and in mitigating these risks, it is prudent to consider risk assessment and management, evaluating possible cyber threats, the company's vulnerabilities to attacks, and how such attacks may impact the company's operations, finances and reputation.

Cybersecurity Challenges in the Digital Era

In this digital era, many organisations worldwide face a plethora of challenges associated with technological integration, lack of or poor management policies, exposure to risks, malware, attacks and vulnerabilities in the Internet of Things (IoT), as well as the human element. Cybersecurity challenges are the risks and constraints that organisations face when protecting digital platforms, data, and operations from evolving cyber threats. Cybersecurity challenges encompass not only the defence against malicious digital attacks but also the management of systemic vulnerabilities arising from rapid digital transformation [3].

Cybersecurity challenges have grown rapidly since organisations rely heavily on digital systems, networks, cloud platforms, and other online technologies. According to Sithole, Odette and Munzhelele [4], many Small and Medium Enterprises (SMEs) adopted digital platforms and tools after COVID-19 but lacked cybersecurity knowledge and were prone to attacks of all kinds. The evolution of technology has led to new variants of cyber threats that leave organisations and individuals vulnerable to financial theft and compromised information, especially personal data that can be used as leverage in the wrong hands. Corporate governance ought to be strategic in tackling cybersecurity, by adopting a realistic framework that takes into consideration its

resources (both financial and human). According to Kumar et al. [5], it was identified that the expansion of digitally enabled infrastructure for small scale organisations was exposed to risks such as legacy-system vulnerabilities, interconnected network failures, and emerging threats like AI-driven or drone-enabled attacks. In a similar article by Sithole et al. [4], SMEs faced threats specific to digital financial platforms, which resulted in mobile money fraud, phishing, ransomware, and insider collusion, where cybersecurity controls were limited. These tell us that cyber challenges exist even in developing countries, which are caused by their technological capabilities and constraints (institutional and resource), therefore it affects organisations' ability to maintain resilience.

It was noted by Kumar et al. [5] that cybersecurity challenges are embedded within socio-technical ecosystems thereby requiring coordinated responses whereas fragmented governance structures and insufficient coordination across agencies weaken the ability to respond to critical cyber incidents. Similarly, Sithole et al. [4] identified the key drivers of cyber challenges in SMEs as insufficient digital knowledge, limited skilled personnel, and weak regulatory enforcement. Consequently, cybersecurity becomes a strategic priority that enhances organisational resilience, ensuring organisations can withstand and recover from challenges in the digital era.

Emerging Technologies and Cybersecurity

The increasing rate of emerging technologies such as artificial intelligence (AI), cloud computing, IoT and interconnected digital systems has significantly intensified organisational cybersecurity risks and challenges. Alnaabi and Al Mahruqi [6] demonstrated that AI is a transformative cybersecurity technology with direct implications for organisational resilience. It highlighted that AI-driven approaches, such as anomaly detection and predictive analytics, significantly improve the ability to identify and respond to cyber threats in almost real time. However, a strategic management perspective would be the proposed Oman Cybersecurity AI Framework (OCAIF) which emphasised that the effectiveness of these technologies depends on organisational readiness, including the capability of the workforce, infrastructure modernisation, and organisational regulatory alignment. Adopting the AI approach should be managed strategically with long-term resilience goals in mind rather than as a standalone technical upgrade. This reinforces that technological potential alone does not translate into resilience without coordinated strategic execution [6].

According to Agyemang et al. [7], their Cybersecurity Readiness Assessment (CSRA) framework represented an emerging methodological innovation that leveraged evaluation models to inform strategic decision-making. The integration of environmental awareness and organisational capabilities is likely to strategically align with cybersecurity initiatives and organisational risk management. Readiness itself is an enabler of technology resilience, allowing prioritised investments, identifying capability gaps, and implementing continuous improvement cycles. The CSRA framework operationalises resilience as a dynamic capability that evolves through iterative assessment and adaptation rather than static compliance [7].

According to Khresat [8], cybersecurity technologies are linked to the practices of regulatory compliance, which incorporate advanced technical controls and standards. By integrating advanced technologies into compliance regimes, this will enhance resilience by strengthening business continuity mechanisms. Strategic management plays a crucial role in aligning technological adoption with regulatory requirements, ensuring that cybersecurity investments contribute to both compliance and operational stability. This

would enable organisations to leverage those mandated controls as pathways for resilience building, particularly in sectors where regulatory frameworks embed technological standards for risk mitigation and recovery [8].

The study by Albustanji and Paulovics [9] highlighted that emerging cybersecurity capabilities are shaped by advances done at the international level of legal and cooperative infrastructures. This relies on digital technologies to share evidence and increased cross-border coordination. Organisational resilience is contingent on the availability of such mechanisms, especially when it involves cyber threats of any kind. There must be inclusion of strategic management to align with internal technological adoption to include engagement with external legal and institutional ecosystems to build resilience. The article suggested adopting frameworks such as the Budapest Convention since it reflects on the growing importance of technologically enabled cooperation (e.g., rapid information exchange systems) in enhancing resilience. This reinforces the view that with emerging technologies in cybersecurity, resilience can be amplified by broader governance structures [9]. Emerging technologies in cybersecurity contribute to organisational cyber resilience however, through strategic management and not in isolation. By employing a strategic perspective, cyber resilience will enable how effective organisations can align their technological capabilities with proper governance, effective resource allocation, and external collaboration.

Cybersecurity Incident and Business Continuity

Strategic management decisions play a crucial role in strengthening cyber resilience to ensure business continuity. Writers von Solms and Upton [10] proposed that resilience is not just a technical function, but is dependent on organisational governance and policies, which should align with modern frameworks such as the NIST Cybersecurity Framework (CSF) 2.0 [10]. The National Institute of Standards and Technology provides voluntary guidelines that organisations can adopt to improve their management of cybersecurity. NIST CSF 2.0 provides a structured approach to identifying, protecting, detecting, responding to and recovering from cyber threats. NIST CSF's recent addition of the 'Govern' function in 2.0 speaks to the said aligned executive strategy with cybersecurity resilience rather than an IT issue.

Cyber resilience depends on strategic governance that is woven into its policy, skills, technology, culture and its people [10]. With this approach, organisations especially SMEs will be better equipped to handle cyber threats/challenges given our technological advancement, with little to no loss of company data. The framework serves as decision support tool to guide organisations systematically to enhance their cyber resilience.

It is important to note that strategic design choices directly influence operational resilience. The 'Westport (WPRT) Cybersecurity Breach' case [11] highlighted that due to the network segmentation of Information Technology systems and manufacturing environments, it limited the operational impact of the cyber incident, causing uninterrupted production. This proved that strategic alignment to redundancy and segmentation eliminated single points of failure and maintained service availability during disruptions [11]. Similarly, geographically distributed data replication confirmed that cyber strategic infrastructure is rooted in long-term managerial planning aimed at ensuring business continuity especially under adverse conditions [12]. These examples contribute to the phenomenon of proper strategic management decisions translated into a cyber resilience system to protect core business functions. By segregating systems (IT versus manufacturing), this will limit cyber-attacks/threats from spreading therefore, a

allowing operations continuity. The NIST CSF provides detailed guidelines on how to manage the segmentation by separating critical operational systems. It also depicts how to deal with cyber breaches in progress, not only prevention.

A conference report from the 2005 Storage Networking World conference featured IT executives who were in discussions about challenges in managing, securing, and recovering hundreds of terabytes to petabytes of data. Ralph Barber, CIO of Holland & Knight, describes replicating data between two data centres (Tampa and Denver) for disaster recovery, and the business impact when Hurricane Wilma knocked out branch offices. This resulted in lost data and no means of generating income from the loss of the clients' information. There should have been primary and secondary core theme backups and replication of data kept offsite at another location for business continuity. This indicated that many organisations still struggle with a gap between cybersecurity priorities and strategic business objectives which weakens its resilience and increases operational exposure.

Conversely, organisations that adopt risk-based approaches and cyber strategies aligned to strategic management can prioritize vital assets while minimizing disruption to revenue generating operations. This supports the argument that resilience is not achieved through isolated IT controls but through integrated strategic management that connects cyber risk, operational priorities, and building business continuity. There should be consistent emphasis placed on resilience-focused strategic management than prevention to maintain continued operations despite inevitable cyber incidents/attacks. Cyber resilience in the digital era is having the ability to anticipate, withstand and recover from disruptions, rather than simply prevention. Therefore, correlation exists between strategic management decisions and business continuity with the alignment of governance and risk management practices, enabling operations to flow with normalcy even in the face of evolving cyber threats. This will ensure fast recovery and less downtime, which ultimately results in little to no financial loss.

Leadership and Organisational Culture

In the digital era, cyber resilience is not only technical acquisition, but also a cultural acquisition of the organisation. In the research studies submitted by Grant [13], information security awareness and training (ISAT) programs were seen as a low priority in the defence sector, as social engineering and employee negligence rose. The research found that organisational culture is a structural driver of whether security programs are taken seriously, resourced, effectively implemented. It also highlighted that people are the ‘weakest link,’ but cultural conditions often prevent the said training that could strengthen them. The author Grant in his article demonstrated that resilience could not be achieved by standard security awareness because of the cultural diversity, which ought to be addressed first. When there is a mismatch with the prevailing culture, then it will be deprioritized, under-resourced, and ignored. It is important to diagnose the culture type in order to prevent mismatch.

Andronache [14] framework on organisational culture was that resilience was not only built from non-episodic awareness but from an embedded culture. He rallied that around the notion of prescribing a periodic training check box to cultivating an embedded security mindset. In the digital era, threats are continuous and ever changing, thus an annual training module cannot generate resilience. Research data shows that cybersecurity governance, its people, and resources account for the bulk of cultural effectiveness. Resilience can only be embedded when security is woven into our daily norms, assumptions, and decisions. The digital era amplifies both speed of threats and cost of human error. As such, technological defences while necessary are

insufficient to cyber resilience. Cybersecurity should be structurally integrated into the culture in the norms, daily operations, hypothetical scenarios, and in our daily behaviour, not just in the policy document on the intranet.

Building Organisational Resilience

Organisational resilience is the ability to anticipate, respond and recover from disruptions while preserving its fundamental purpose and values [15]. This refers to the organisation's capacity to respond to crises and adapt to change. Resilience builds strength especially during unexpected technological disruptions (cyber attacks) but can continue to operate effectively while improving from the situation. This capability is essential in today's complex and uncertain business environment, as it enables organisations to remain sustainable over the long term.

An article on cybersecurity capabilities by Malatji et al. [16] highlighted how critical infrastructure cybersecurity capability frameworks are developed to function with five NIST framework components, which include Identify, Protect, Detect, Respond and Recover. These five functions should be included in the organisation's risk management and corporate governance. It is vital to include cybersecurity resilience in corporate governance because of an organisation's heavy reliance on digital technology. Therefore, put provisions in place to build resilience, ensuring that organisations are better prepared for a cyber attack/threat system failure, reducing downtime, loss of company data, and ultimately any financial loss.

According to research studies [17], building organisational cyber resilience requires sharing information (external) in conjunction with the organisation's readiness (internal) to act on that information captured in a synergy dependency (Network Flattening, Alert Paralysis, Operational Coupling, and Relational Weaponization), which refers to how external governance effectiveness is contingent on internal controls. While this theory reinforces cross-boundary governance to counter the escalation of cyberattacks, the need for governance is identified as essential to cyber resilience. It adds to the fact that building resilience is not just an IT function but an organisational function to ensure business continuity. Similarly, a recent study conducted by the Design Science Research [7] highlighted a two-tier assessment framework that evaluated the external cybersecurity environment, including its regulation, national strategy and institutional support, in conjunction with an organisation's internal readiness across governance, technical controls, awareness and culture. Again, this study reemphasizes that resilience is built on cybersecurity integrated into corporate governance through external capabilities.

However, a study was conducted on the digital paradox in China's construction sector [17], highlighting that heavy digital investment often fails due to organisational resilience. The study argued that while digital investment improves the performance of an organisation, it is also important to strengthen its ability to withstand and recover from disruptions. The study found that organisational resilience is built on three capacities; an organisation's intelligence, connectivity and analytics proving, connectivity to be the largest. This is a long-term effect that increases organisations' performance, its capacity for robustness, data-driven risk prediction for agility, and strategic alignment for integrity [17]. While this study specifically speaks to organisational resilience, it is imperative to ensure that organisations are in a state of strength digitally in order to withstand cyber-attacks and it starts with proper strategic decisions aligned with cyber resilience. To build organisational resilience it is prudent to have the right cybersecurity capabilities in place, and to ensure the capabilities are operational while taking note of their readiness. These elements contribute to a

better organisational performance while leveraging resilience in the digital era.

Cybersecurity Best Practices Framework

Adopting a best practice cybersecurity framework will help organisations achieve the best outcomes in protecting systems, data/information, and networks from cyberattacks/threats by utilising proven methods and managing their risks. The best-practice framework tells organisations how to stay secure and how to align their security measures in a consistent manner to ensure resilience. There are several research studies with a number of best practices highlighting the following frameworks: Artificial Neural Network Interpretive Structural Modelling Framework (ANN-ISM); National Institute of Standards and Technology (NIST) Cybersecurity Framework (CSF); Critical Infrastructure Capability Framework; MITRE Adversarial Tactics, Techniques, and Common Knowledge (ATT&CK); Cyber Kill Chain; Zero Trust Architecture (ZTA); European Cybersecurity Skills Framework (ECSF); NIST + ATT&CK + Cyber Kill Chain [18]; and ISO/IEC 27001.

The NIST CSF provides guidelines that organisations can adopt to improve their cybersecurity management. NIST CSF 2.0 presents a structured approach to detect, identify, respond to, recover from and protect against cyber threats. ISO/IEC 27001 is an internationally recognized standard focused on the creation, maintenance, and continual improvement of an Information Security Management System (ISMS). ISO/IEC 27001 is an information security management standard that provides organisations with a structured framework to safeguard their information assets and ISMS, covering risk assessment, risk management and continuous improvement [19].

Results: Existent Gaps in the Literature

The findings revealed from the literature indicated that cybersecurity is a function that is managed in isolation. The related papers reviewed on cybersecurity's readiness assessment frameworks [7] identified gaps such as limited readiness interpretability, maturity models with weak contextualisation, and awareness measurement isolated from governance [7].

In addition, this hypothesis is untested and therefore, the literature relative to its specificity is limited and/or non-existent. While the literature on resource-based view is estimated, the empirical data is not validated in the context of cybersecurity. This is a significant gap between the theoretical and practical integration of strategic management with cybersecurity in SMEs. Most literature addresses either one or the other. However, the objective is to bridge this gap through the information gathered from the small to medium enterprises targeted in the urban area of Guyana; Georgetown and demonstrate how the alignment between these two domains enhances resilience.

In addition, SMEs were forced to move their operations to a digital platform during and post-COVID and lacked the cybersecurity knowledge to match. As a result, this highlights a practical gap that was addressed in the results article on a study of SMEs in Georgetown, Guyana on how to enhance cyber resilience (under review).

Discussion

A consistent finding across the eight strands of literature is that the possibility of cyber resilience is through strategic management rather than technical controls alone [10]. The theoretical strand shows the field arriving at this position through a natural extension of its foundations, where classical and industrial organisation theories emphasized its positioning and planning, the Resource-Based

View directs attention to governance, internal capabilities, culture and readiness that determine whether technology investments translate into resilience [2, 17].

Evidence on cyber challenges reinforces this as well, as the threats confronting developing-economy SMEs are socio-technical rather than purely technical. Kumar et al. [5] found that challenges are embedded within socio-technical ecosystems which require coordinated, tested responses, whilst Sithole et al. [4] identified insufficient digital knowledge, limited skilled personnel and weak regulatory enforcement as key drivers in SMEs that digitised rapidly after COVID-19. This places cybersecurity in a strategic emergency as fragmented governance and under-resourced institutions cannot be fixed only at the IT level.

The emerging technology and framework strands carry the review's vital focus, technological potential does not become resilience without strategic execution. Alnaabi and Al Mahruqi [6] demonstrated that AI-driven approaches improve threat detection in near real time, yet their effectiveness depends on organisational readiness, regulatory alignment, and workforce capability. This was a condition formalised by Agyemang et al. [7], whose Cybersecurity Readiness Assessment framework operationalises resilience as a dynamic capability rather than compliance. The incident evidence points the same in both directions, the Westport (WPRT) breach showed that strategic design choices such as network segmentation preserved operations during an active attack [11], whereas the Hurricane Wilma data-loss episode depicted the gap between cybersecurity priorities and business objectives, which converted disruption into business failure [12].

Leadership and culture emerge as the binding constraints and Grant [13] found that information security awareness and training programmes were deprioritised and under-resourced where organisational culture was mismatched. On the other hand, Andronache [14] argues that annual, check the box training cannot generate resilience against those continuously evolving threats; as security must be integrated into daily norms and decisions. Malatji et al. [16] similarly situated the five NIST functions within corporate governance and risk management, and Zhang et al.'s evidence of a digital paradox, in which heavy investment fails without organisational capacities on intelligence, connectivity and analytics, confirms that investment without strategic integration is wasted.

These findings are coherent but small in context, since the reviewed studies address Oman, Uganda, Jordan, India and China, and empirical evidence on strategic management and cybersecurity in developing economies, and in the Caribbean in particular, remains limited. The research addressed this gap. The small to medium-sized businesses in Georgetown, Guyana, operate within an emerging regulatory environment including the Cyber Crime Act 2018 and the Data Protection Act 2023 [20, 21]. The literature predicts that resilience will track the quality of strategic integration rather than the volume of technology, a proposition the empirical phase of the study tested.

Conclusion

Strategic management is a complex field that draws on a rich theoretical foundation and continues to evolve by adapting to its challenges and opportunities presented in this digital era. Across all eight strands of literature, the consistent position is that cyber resilience depends on strategic governance integrated into policy, skills, technology, culture and people, and not simply on information technology function. Therefore, integrating strategic management with cybersecurity, is essential to build organisational resilience especially when cybersecurity is aligned with strategic planning. This can strengthen businesses' capacity to prepare for, respond to and recover from

cyberattacks while maintaining its business continuity, reputation and financial stability.

Conflict of Interest

The author declares no conflict of interest.

Ethical Approval

This study forms part of a doctoral research programme conducted in accordance with the ethical standards of Universidad Central de Nicaragua and Texila American University. The manuscript is a review of published literature, therefore no primary data involving human participants were included and all sources are publicly available and duly acknowledged.

Data Availability

This manuscript reviewed published literature; of which no new datasets were generated. All data supporting the findings were drawn from the published sources cited in the reference list, which are publicly available.

Author Contributions

Charles Paul Shurland is the sole author responsible for the conceptualization, literature search, synthesis, scribing and review of the manuscript.

Funding

The author funded this research.

Acknowledgements

Sincere gratitude is extended to family, Dr. Narayanasamy Siddaiyan Santhi, the Research Committee, members of Thesis Guidelines Formulation Committee and the research scholars who graciously assisted with the completion of this research.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art020

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Marital Status, Ergonomic Challenges, and Academic Performance among University Students in Nigeria

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Cite this article as: OGBE Alex, Michael Tomori, Emelonye Amaka Doris. Marital status, ergonomic challenges, and academic performance among university students in Nigeria. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art020**

Received: 23.07.2026
Accepted: 25.09.2026
Published: 30.10.2026

Article Type: Original Research

Abstract *Ergonomic challenges in university learning environments are increasingly recognized as important factors influencing student health and academic performance. However, there is limited evidence on how these challenges interact with socio-demographic factors such as marital status, particularly in low- and middle-income countries. This cross-sectional study was conducted among 352 students at the University of Calabar, Nigeria. Data were collected using a structured online questionnaire that incorporated elements of the Standard Nordic Musculoskeletal Questionnaire. Descriptive statistics, correlation analysis, and logistic regression were applied to examine the relationship between marital status, cumulative ergonomic challenges, and academic performance. Married students accounted for 2.56% of the study population. Commonly reported ergonomic challenges included musculoskeletal strain, poor lighting, non-adjustable furniture, and inadequate learning infrastructure. A moderate positive relationship was observed between cumulative ergonomic burden and academic performance impairment (r = 0.508), although this was not statistically significant. In the unadjusted analysis, married female students had higher exposure to ergonomic stressors and poorer academic outcomes compared to their male counterparts (OR = 2.00). However, after adjusting for ergonomic burden, this relationship reversed (AOR = 0.533), suggesting that the observed differences were largely driven by unequal exposure to environmental stressors rather than gender. Ergonomic challenges are a significant but often overlooked determinant of academic performance among university students. These findings highlight the need for institution-wide ergonomic interventions, particularly for vulnerable groups, to improve learning conditions, reduce physical strain, and support better academic outcomes.*

Keywords *Academic Performance, Ergonomics, Marital Status, Musculoskeletal Disorders, Nigeria University Students.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art020

Introduction

The demographic composition of contemporary universities has changed considerably over the years, transforming higher education institutions from environments predominantly occupied by single young adults into increasingly diverse settings that accommodate students with varying social and familial responsibilities, including married individuals [1]. Although higher education is inherently demanding, married students are often required to navigate a complex combination of academic obligations, family commitments, financial responsibilities, and competing time demands that are less pronounced among their unmarried counterparts [2]. Balancing these multiple roles places substantial cognitive and emotional demands on married students, with potential implications for their well-being and academic success [1]. Moreover, the increasing adoption of hybrid learning approaches and extended study schedules has resulted in students spending prolonged periods at formal and improvised workstations. Consequently, the physical characteristics of the learning environment have become increasingly important determinants of students' educational experiences and academic outcomes [3, 4].

Despite the expanding literature on institutional and psychosocial stressors affecting students, limited attention has been devoted to understanding how physical environmental factors interact with individual socio-demographic characteristics. Physical ergonomics, which focuses on optimizing the interaction between individuals and their work environments, plays a crucial role in promoting comfort, sustaining concentration, and enhancing cognitive efficiency during learning activities [4, 5]. Within educational settings, inadequately designed learning environments characterized by unsuitable furniture, insufficient lighting, and poor spatial arrangements often compel students to adopt prolonged and uncomfortable postures [2, 6]. Persistent exposure to these unfavorable conditions may lead to physical exhaustion and the development of musculoskeletal disorders (MSDs), thereby reducing attention span, impairing information retention, and diminishing overall learning motivation [4, 5, 7]. Although ergonomic deficiencies affect the student population, married students may be particularly susceptible because of fragmented study schedules, the need to alternate between home and campus workstations, and limited awareness of ergonomic principles [4, 8, 9].

The combined effects of domestic responsibilities and physical strain may create a cycle that adversely affects learning and academic achievement [10]. Previous studies have demonstrated that elevated academic stress and psychological demands can intensify physical discomfort, transforming transient musculoskeletal symptoms into persistent impediments to effective learning [2, 11]. Consequently, when married students are exposed to ergonomically unfavorable study environments, their ability to maintain concentration, process complex information, and sustain academic performance may be compromised [4, 12]. While substantial research has examined ergonomic conditions among university staff and academic personnel [8, 13], comparatively little attention has been directed toward students, despite their continuous engagement in intellectually demanding activities that expose them to similar environmental risks [14, 15]. Therefore, understanding the interrelationship between marital status, ergonomic challenges, and academic performance is essential for developing evidence-based institutional strategies aimed at safeguarding student health, promoting well-being, and enhancing educational outcomes [4, 5, 16].

Materials and Methods

Study Design and Setting

This study employed an online-based cross-sectional design to investigate the relationship between ergonomic challenges and academic performance among students of the University of Calabar, with particular emphasis on married students. The cross-sectional approach enabled the assessment of exposure to ergonomic stressors and their associated effects on academic outcomes at a single point in time during the study period, which spanned from May to June.

Data collection was conducted entirely through an online platform using Google Forms, thereby eliminating the need for physical interaction between the researchers and participants. The study was carried out among students of the University of Calabar, a second-generation federal university located in Calabar, Cross River State, Nigeria [17]. Owing to its heterogeneous student population drawn from diverse socio-cultural and educational backgrounds, the institution provided an appropriate setting for examining the interplay between marital status, ergonomic challenges, and academic performance.

Study Population and Eligibility Criteria

The target population comprised registered undergraduate and postgraduate students of the University of Calabar who were actively enrolled in full-time academic programmes at the time of the study [18]. To be eligible for participation, respondents were required to be bona fide students of the institution and enrolled on a full-time basis.

Students who simultaneously are both staff and students were excluded from the study to minimize potential occupational-related confounding. Similarly, students enrolled in part-time or weekend programmes, as well as individuals engaged in regular employment alongside their studies, were excluded because of the additional occupational exposures that could influence their ergonomic experiences. Furthermore, questionnaires with incomplete responses were excluded from the final analysis to ensure data completeness and enhance the reliability of the findings.

Sample Size Determination and Sampling Technique

The sample size for the study was determined using the Kish and Leslie formula proposed in 1965 for cross-sectional studies [19, 20]. Based on the calculation, a minimum sample size of 357 participants was obtained. However, after data cleaning and the exclusion of incompletely filled questionnaires, a total of 352 valid responses were included in the final analysis. The respondents' rate was approximately 92.3%.

Google Forms served as the primary data collection platform, providing an efficient means of reaching a geographically dispersed student population and facilitating the collection of information on sensitive variables. Google Forms served as the primary data collection platform, providing an efficient means of reaching a geographically dispersed student population and facilitating the collection of information on sensitive variables. Although initial stratification across academic departments was intended to ensure broad disciplinary representation, the actual recruitment relied on online dissemination through WhatsApp, peer networks, and snowball/continued sharing. Consequently, the sampling technique operated primarily as a non-probability convenience and snowball sampling approach, which inherently introduces potential selection bias and limits the generalizability of the findings.

Data Collection Procedure and Instruments

Data was collected using a structured and pre-tested questionnaire designed specifically for the study. The instrument incorporated selected components of the Standard Nordic

Musculoskeletal Questionnaire, which has been widely utilized for assessing ergonomic exposures and musculoskeletal symptoms [21]. The questionnaire was adapted to address the objectives of the present study and was hosted on the Google Forms platform to ensure ease of access and broad coverage across the various academic departments within the University of Calabar.

The survey link was disseminated electronically through WhatsApp platforms with the assistance of student contacts and peer networks within and outside the university community. To maximize response rates, periodic reminders were sent to participants who had previously received the survey link, while additional respondents were recruited through continued sharing of the link across relevant student groups. This approach facilitated widespread participation and enhanced the overall response rate of the study.

Study Variables

The primary outcome variable in this study was academic performance, operationally defined and measured using self-reported grade point categories and academic standing, subsequently dichotomized into poor academic performance (representing below-average cumulative performance) and good academic performance. 'Academic performance impairment' was measured by quantifying the number of self-reported academic disruptions—such as reduced concentration, examination underperformance, and cognitive fatigue—attributable to environmental discomfort. The cumulative ergonomic-burden score was calculated as a composite index derived from the total count of individual physical, environmental, and equipment-related ergonomic stressors experienced by each participant across a 20-item checklist, with higher cumulative scores reflecting heavier overall ergonomic strain.

In addition to the primary variables, selected socio-demographic characteristics, including age and gender, were examined to explore their interaction with marital status and academic performance. These variables were considered important in understanding potential variations in the effects of ergonomic challenges across different demographic groups.

Data Management and Statistical Analysis

Data obtained from the online survey was cleaned, coded, and analyzed using STATA version 14. Descriptive statistics were employed to summarize the characteristics of the study population. Categorical variables were presented as frequencies and percentages, while appropriate summary measures were used to describe continuous variables.

For inferential analysis, bivariable analyses were initially performed to examine the association between independent variables and academic performance. Variables with a p-value less than 0.05 were considered statistically significant and were subsequently considered for further analysis. Correlation analysis was conducted to assess the relationship between cumulative ergonomic burden and academic performance indicators.

To evaluate the influence of marital status and other external factors on academic performance among married students, crude odds ratios (ORs) and adjusted odds ratios (AORs) with their corresponding confidence intervals were estimated using logistic regression models. Adjustment for potential confounding variables enabled the determination of the independent contribution of cumulative ergonomic challenges to academic performance outcomes among the married student cohort. Statistical significance was established at a p-value of less than 0.05.

Handling of Missing Data

Prior to analysis, the dataset was examined to assess data completeness and to determine the extent and pattern of missing values. The proportion of missing data was found to be less

than 5%, indicating a minimal level of incompleteness. Given the relatively small proportion of missing observations and the cross-sectional nature of the study, complete-case analysis was considered appropriate.

Participants with incomplete responses were excluded from the final analysis to ensure the integrity and consistency of the dataset. Consequently, all statistical analyses were performed using complete recorded data, thereby minimizing potential bias and enhancing the reliability of the study findings.

Results

A total of 352 students participated in the study. The mean age of the respondents was 23.30±2.10 years, with the majority belonging to the 21–25 years age group (n = 315, 89.49%). Male participants constituted a slightly higher proportion of the study population (n = 185, 52.56%) compared to females (n = 167, 47.33%), resulting in a male-to-female ratio of approximately 1.11:1.

With respect to marital status, only a small proportion of the participants were married, accounting for 2.56% (n = 9) of the total sample (6 men and 3 women). Given this extremely small subgroup size, subsequent gender-specific comparisons, cross-tabulations, and logistic regression models yield highly unstable odds ratio (OR) and adjusted odds ratio (AOR) estimates. Consequently, these quantitative models cannot support meaningful statistical inference and must be interpreted strictly as descriptive observations requiring empirical verification in adequately powered samples.

Similarly, while the descriptive data within the small married cohort initially suggested apparent trends in gender-based vulnerability, adaptive capacity, or environmental thresholds, interpretations invoking concepts such as 'gendered pattern of vulnerability,' 'equal or greater academic resilience,' 'psychological resilience,' and an 'environmental tipping point' go beyond what data from only 3 married women and 6 married men can reliably demonstrate. These conceptual observations are discussed purely as preliminary, qualitative hypotheses rather than verified empirical phenomena

The distribution of ergonomic challenges according to marital status is presented in Table 1. Overall, married students appeared to experience a greater burden of ergonomic stressors compared with other categories of participants. Furthermore, gender-specific analysis among married students revealed that female participants reported a higher cumulative exposure to ergonomic challenges than their male counterparts. A summary of the gender-specific distribution of these stressors among married students is presented in Table 2.

The most reported ergonomic challenges included musculoskeletal disorders, inadequate illumination, irregular power supply for night study, excessive environmental noise, and anthropometric incompatibility between students and available furniture.

Analysis of academic outcomes demonstrated that married female students experienced poorer academic performance compared to the married male students. This pattern was attributed to the greater burden of ergonomic stressors experienced by female participants, which was frequently accompanied by reduced concentration and diminished learning efficiency.

Correlation analysis revealed a moderate positive relationship between cumulative ergonomic burden and total academic performance impacts ($r = 0.508$); however, this relationship did not attain statistical significance ($p = 0.163$). While the sample demonstrates a descriptive trend where higher ergonomic stressors align with worsening academic outcomes, the lack of statistical significance suggests this pattern should be interpreted with caution and verified with a larger sample size.

Further analysis using odds ratios demonstrated that, prior to adjustment for external factors, married female students had

twice the odds of poor academic performance compared with their married male counterparts (OR = 2.00). However, after controlling for potential confounding factors through logistic regression analysis, the adjusted odds ratio for female students was 0.533, whereas cumulative ergonomic burden was associated with an adjusted odds ratio of 1.269. The distribution of academic performance across gender within the married cohort is presented in Table 3. These findings suggest that the elevated risk initially observed among married female students may be largely attributable to their disproportionate exposure to multiple ergonomic stressors rather than to gender itself.

Table 1. Ergonomic Challenges and Students' Marital Status

Ergonomic Challenges	**Married (n = 9)**	**Not Married (n = 306)**	**Divorced (n = 10)**	**Co-Habiting (n = 1)**	**Dating (n = 26)**
Incorrect Seating Habit	6 (66.7%)	174 (56.9%)	6 (60.0%)	1 (100%)	17 (65.4%)
Musculoskeletal Disorders	5 (55.6%)	138 (45.1%)	3 (30.0%)	1 (100%)	15 (57.7%)
Visual challenges	5 (55.6%)	161 (52.6%)	6 (60.0%)	0 (0.0%)	17 (65.4%)
Poor illumination of lecture hall	2 (22.2%)	122 (39.9%)	4 (40.0%)	0 (0.0%)	12 (46.2%)
Absence of curtains or blinds in lecture halls	6 (66.7%)	187 (61.1%)	6 (60.0%)	1 (100%)	15 (57.7%)
Using laptops without a laptop stand	6 (66.7%)	188 (61.4%)	7 (70.0%)	1 (100%)	14 (53.8%)
Lack of constant power for night study	3 (33.3%)	143 (46.7%)	4 (40.0%)	0 (0.0%)	10 (38.5%)
High level noise (Occasionally)	4 (44.4%)	120 (39.2%)	2 (20.0%)	0 (0.0%)	10 (38.5%)
Lack of adjustable chairs and tables	6 (66.7%)	187 (61.1%)	6 (60.0%)	0 (0.0%)	14 (53.8%)
Anthropometric incompatibility with furniture	5 (55.6%)	152 (49.7%)	5 (50.0%)	0 (0.0%)	12 (46.2%)
Lack of privacy in the students' hostels	6 (66.7%)	121 (39.5%)	5 (50.0%)	0 (0.0%)	9 (34.6%)
Lack of ergonomically designed bed in hostels	7 (77.8%)	137 (45.4%)	5 (50.0%)	0 (0.0%)	0 (0.0%)

Table 2. Ergonomic Challenges Relationship with Gender Distribution

Ergonomic Challenge Description	**Male (n = 6)**	**Female (n = 3)**	**Total Married (N = 9)**
Incorrect seating habit	4 (66.7%)	2 (66.7%)	6 (66.7%)
Musculoskeletal disorders	3 (50.0%)	2 (66.7%)	5 (55.6%)
Visual challenges	3 (50.0%)	2 (66.7%)	5 (55.6%)
Poor illumination of lecture hall	2 (33.3%)	0 (0.0%)	2 (22.2%)
Absence of curtains or blinds in some lecture halls	3 (50.0%)	3 (100.0%)	6 (66.7%)
Using laptops without a laptop stand	3 (50.0%)	3 (100.0%)	6 (66.7%)

Viewing angle and wrong monitor height	1 (16.7%)	3 (100.0%)	4 (44.4%)
Wrong seating arrangement in class	3 (50.0%)	1 (33.3%)	4 (44.4%)
Lack of customized seats for students of special needs	4 (66.7%)	2 (66.7%)	6 (66.7%)
Lack of constant power supply for night study/reading	2 (33.3%)	1 (33.3%)	3 (33.3%)
Incorrect backpack posture	2 (33.3%)	1 (33.3%)	3 (33.3%)
Prolonged sitting in laboratories (>3 hours)	3 (50.0%)	2 (66.7%)	5 (55.6%)
High level of noise (occasionally)	2 (33.3%)	2 (66.7%)	4 (44.4%)
Lack of relaxation spots	2 (33.3%)	2 (66.7%)	4 (44.4%)
Lack of cable management in the ICT laboratory	2 (33.3%)	2 (66.7%)	4 (44.4%)
Lack of adjustable tables/chairs	3 (50.0%)	3 (100.0%)	6 (66.7%)
Anthropometric incompatibility with provided seats/tables	2 (33.3%)	3 (100.0%)	5 (55.6%)
Lack of orientation in proper application of ergonomic principles	2 (33.3%)	3 (100.0%)	5 (55.6%)
Lack of privacy in the hostel	3 (50.0%)	3 (100.0%)	6 (66.7%)
Lack of ergonomically designed bed	4 (66.7%)	3 (100.0%)	7 (77.8%)

Table 3. Academic Performance Outcome Distribution by Gender Among Married Students

Gender	**Poor Academic Performance**	**Good Academic Performance**	**Total**
Married men	3	3	6
Married women	2	1	3
Total	5	4	9

Gender-Based Distribution of Ergonomic Burdens and Academic Outcomes

When the data set was disaggregated by gender, a clear divergence emerged in the pattern and intensity of ergonomic stressors and their associated academic consequences among married students. Married female students (n = 3) exhibited a substantially higher cumulative ergonomic burden, with a mean score of 16.0 ergonomic challenges and an average of 3.67 reported academic performance impairments. In contrast, married male students (n = 6) recorded a comparatively lower mean ergonomic challenge score of 9.17 and an average academic impact score of 2.67.

A more nuanced inspection of the distribution revealed a marked heterogeneity among male respondents, whose ergonomic exposure ranged widely from 0 to 18 challenges. Conversely, female respondents demonstrated a consistently high and clustered exposure pattern, with individual scores of 10, 17, and 21 ergonomic challenges respectively. This uniform elevation suggests a more systemic and sustained exposure to adverse ergonomic conditions among married female students.

This pattern corresponded with a higher frequency of academic difficulties among

females, particularly in relation to reduced concentration capacity, examination underperformance, and reported academic frustration. The findings suggest that ergonomic stress may exert a more concentrated and predictable effect within this subgroup, potentially due to compounding domestic and academic role demands.

Age-Based Distribution of Ergonomic Challenges and Academic Performance

Analysis by age group further revealed differentiated exposure-response patterns between ergonomic stressors and academic performance outcomes among married students.

Within the 21–25 years age group (n = 6), the distribution was bimodal. Two participants reported complete insulation from ergonomic stressors (0 ergonomic challenges) and correspondingly minimal academic disruption (<1 academic impact). However, the remaining four participants exhibited pronounced vulnerability, with moderate to high ergonomic exposure associated with an average of more than five academic performance impairments. This indicates a subgroup within this age category experiencing disproportionate sensitivity to environmental and ergonomic constraints.

In the 31–35 years age bracket (n = 2), participants demonstrated relatively high ergonomic exposure, with scores ranging between 12 and 17 challenges. Despite this elevated physical burden, this cohort exhibited minimal academic disruption, with an average of only 0.5 reported performance impacts. This suggests a potential adaptive or compensatory capacity within this cohort, reflecting greater resilience or coping mechanisms in managing ergonomic strain without significant academic deterioration.

The 36–40 years category consisted of a single participant who reported an extreme ergonomic burden (18 challenges) accompanied by a complete collapse of academic performance indicators (100% impairment across measured outcomes). While interpretive generalization is limited due to sample size, this case illustrates a possible threshold effect, where excessive ergonomic strain overwhelms adaptive capacity.

Correlational Analysis

The relationship between cumulative ergonomic burden and total academic performance impairment was assessed using correlation analysis, yielding a moderately strong positive association ($r = 0.508$, $p = 0.163$). Although the result did not reach statistical significance at conventional thresholds, likely due to the limited sample size, larger studies are needed to confirm this relationship.

Specifically, the positive coefficient suggests that increases in ergonomic challenges are associated with proportional increases in academic performance impairment. This pattern supports the conceptual assumption that poor ergonomic conditions contribute to reduced academic efficiency, primarily through mechanisms such as decreased concentration, physical discomfort, and cognitive fatigue.

However, given the small sample size concerned, these findings should be interpreted as exploratory rather than confirmatory, warranting further investigation with larger and more balanced cohorts.

Odds Ratios and Adjusted Odds Ratios

Intra-cohort Analysis Among Married Students (N = 9)

A contingency analysis was conducted to examine the association between gender and academic performance within the married student cohort as shown in Table 3.

From this distribution, the odds of poor academic performance were calculated as follows:

1. Married men: 3/3 = 1.00
2. Married women: 2/1 = 2.00

Crude Odds Ratio (OR)

The crude odds ratio comparing females to males was computed as:

OR} = Odds of female/ Odds of male 2.00/1.00 = 2.00

This indicates that, without adjusting for confounding variables, married female students exhibited twice the odds of poor academic performance compared to their male counterparts.

Adjusted Odds Ratio (Logistic Regression Model)

To account for potential confounding effects, a logistic regression model was applied, incorporating cumulative ergonomic burden as an adjustment variable. The adjusted estimates were as follows:

1. Female (Adjusted Odds Ratio, AOR): 0.533
2. Cumulative ergonomic challenges (AOR): 1.269

Interpretation

After controlling for cumulative ergonomic exposure, the gender effect was substantially reversed. Married female students demonstrated a 46.7% reduction in the odds of poor academic performance relative to married male students, calculated as:

1−0.533 = 0.467 that is 46.7%

This suggests that the initially observed higher risk among females in the crude analysis was largely attributable to differential exposure to ergonomic and infrastructural stressors rather than intrinsic gender-based academic vulnerability.

Discussion

This cross-sectional study examined the intersection between marital status, ergonomic hazards, and academic performance within a Sub-Saharan African university context. The central premise of the investigation was that the alignment—or misalignment—between students and their physical learning environments plays a critical role in shaping academic outcomes. However, within this context, students are simultaneously exposed to physical ergonomic constraints [4] while also navigating complex socio-domestic responsibilities and institutional academic demands, particularly among married students [1]. The findings of this study demonstrate a clear, gendered pattern of vulnerability in which ergonomic challenges significantly disrupt learning consistency, concentration capacity, and overall academic performance within the university environment.

Descriptive analysis revealed a high and widespread prevalence of ergonomic deficiencies across both academic and residential environments. Among the married student cohort (N = 9), structural inadequacies were pervasive and multifactorial. Notably, 77.8% of participants reported the absence of ergonomically appropriate bedding in their hostels, while 66.7% reported multiple environmental constraints, including improper seating posture, lack of window blinds or curtains in lecture halls, absence of laptop support equipment, insufficient availability of adjustable desks and chairs, and limited privacy within student accommodation settings.

These conditions collectively compel students to adopt sustained awkward postures during prolonged periods of study and academic engagement. Such findings are consistent with existing ergonomic literature, which has established that prolonged exposure to structurally inadequate learning environments contributes to musculoskeletal disorders (MSDs), chronic physical fatigue, and reduced functional productivity among university students [2].

In this study, the descriptive evidence further corroborates this theoretical pathway, as 55.6% of married participants reported experiencing musculoskeletal discomfort and visual strain. These outcomes highlight the direct physiological consequences of sustained

ergonomic deprivation within academic environments.

From an environmental ergonomics perspective, factors such as inadequate lighting, non-adjustable furniture, and poorly designed study spaces significantly impair cognitive endurance and information processing capacity. When students are required to adapt continuously to suboptimal physical conditions, their ability to sustain attention, retain information, and engage in prolonged academic tasks becomes structurally compromised [5]. The present findings align strongly with this established body of evidence, reinforcing the role of environmental design as a determinant of academic functionality.

A key finding of this study is the pronounced gender-based disparity in cumulative ergonomic burden and its associated academic consequences among married students. Although married male students constituted the majority of the sample in a 2:1 ratio, multivariate analysis revealed that married female students experienced disproportionately worse academic outcomes when ergonomic exposure was considered.

This discrepancy is further clarified by exposure-level data, which indicate that married female students experienced a substantially higher mean number of ergonomic stressors ($M = 16.0$) compared to their male counterparts ($M = 9.17$). This suggests that gender differences in academic performance are not solely attributable to marital status or academic workload but are significantly mediated by differential exposure to adverse physical learning environments.

Taken together, these findings point toward an interactional effect in which gender, marital responsibilities, and ergonomic conditions converge to shape academic vulnerability. In particular, the compounded burden experienced by married female students may reflect both environmental disadvantage and increased role strain, thereby intensifying their susceptibility to academic disruption within the university setting.

A more granular examination of ergonomic exposure patterns reveals a pronounced and systematic disparity between married female and male students. All married female participants (100%, $n = 3$) reported complete absence of key ergonomic supports across multiple environmental dimensions. These included lack of window curtains or blinds, no access to laptop stands, inappropriate viewing angles or monitor positioning, absence of adjustable seating or desks, poor anthropometric compatibility with available furniture, lack of institutional ergonomic orientation, and complete absence of adequate privacy and structurally appropriate bedding within hostel environments.

In contrast, exposure levels among married male students across these same variables ranged between 16.7% and 66.7%, indicating substantially lower and more heterogeneous levels of environmental deprivation. Collectively, this disparity accounts for a substantial proportion of the observed variation in academic impairment, with female students bearing a disproportionate share of the overall negative ergonomic burden within the study population.

This extreme clustering of environmental disadvantages among female participants indicates a structurally uniform vulnerability profile, whereby married female students consistently operate under higher ergonomic stress conditions compared to their male counterparts. This sustained exposure pattern plausibly explains the elevated frequency of poor academic outcomes observed within this subgroup. Supporting this interpretation, existing evidence suggests that persistent exposure to localized physical strain acts as a systemic barrier to learning, contributing to increased rates of examination failure, reduced cognitive focus, and heightened academic frustration [7].

The inferential statistical analysis further quantified the relationship between cumulative ergonomic burden and academic performance outcomes, with particular emphasis on gendered differences. Correlation analysis demonstrated a moderately strong positive relationship between cumulative ergonomic burden and total academic performance impairment ($r = 0.508$, $p = 0.163$). Although this association did not achieve conventional statistical significance—likely due to the limited sample size—the magnitude and direction of the coefficient indicate a clear and consistent trend: increasing infrastructural deficiencies and postural strain are associated with proportional deterioration in academic performance outcomes.

This finding aligns with prior research by Osita et al. [8], which established that inadequate physical learning environments significantly impair cognitive efficiency and academic productivity among university populations. The present study extends this evidence by demonstrating that such ergonomic constraints operate not only as environmental stressors but also as structured determinants of academic inequality within subgroups defined by gender and marital status.

Further insight is provided through the comparison of crude and adjusted odds ratios. In the unadjusted model, married female students exhibited twice the odds of poor academic performance compared to their male counterparts (OR = 2.00). However, when cumulative ergonomic burden was incorporated into a logistic regression model as a confounding variable, a notable reversal in effect direction was observed. The adjusted odds ratio for female students decreased to 0.533 (AOR = 0.533), indicating a 46.7% reduction in the odds of poor academic performance relative to males under equivalent ergonomic conditions.

These findings suggest that the observed gender differences may largely reflect unequal ergonomic exposure: the initially observed elevated risk among married female students is not inherently gender-driven but is largely explained by differential exposure to adverse ergonomic environments. In other words, when subjected to comparable levels of ergonomic stress, married female students demonstrate equal or greater academic resilience than their male counterparts.

It is important to acknowledge, however, that environmental and structural constraints are not randomly distributed and cannot be analytically abstracted from the lived realities of the population under study. External conditions shape behavioral and cognitive outcomes in ways that are cumulative and difficult to isolate completely in real-world settings. Within this context, the findings suggest that the observed disparities reflect structural inequality in environmental exposure rather than intrinsic differences in academic capability.

Moreover, psychological stress and academic pressure have been shown to exacerbate the physiological effects of ergonomic strain, intensifying fatigue, musculoskeletal discomfort, and cognitive overload [6]. This interaction is particularly relevant for married female students, who often experience a compounded burden arising from dual-role responsibilities across domestic and academic domains.

Consequently, the findings support a cyclical model in which inadequate ergonomic conditions interact with psychosocial stressors to fragment study routines across multiple non-optimized environments (home and campus). This dual-exposure pattern reinforces cumulative fatigue and reduces sustained academic efficiency, thereby perpetuating a feedback loop of performance impairment.

In terms of age distribution, the findings further indicate that age acts as a moderating factor in determining students' capacity to withstand ergonomic stressors and their associated academic consequences. Within the 21–25 age group (n = 6), responses exhibited a pronounced bimodal distribution. Two

participants reported complete insulation from ergonomic constraints (0 challenges), while the remaining four experienced substantial cumulative strain, with an average exceeding five distinct academic performance impairments. This suggests marked intra-cohort heterogeneity, where a subset of younger married students demonstrates high vulnerability to environmental stressors, while others appear relatively unaffected.

In contrast, married students within the 31–35 age bracket (n = 2) reported comparatively high ergonomic exposure, with strain scores ranging between 12 and 17 challenges. Despite this elevated physical burden, this cohort exhibited minimal academic disruption, with an average of only 0.5 reported performance impacts. This pattern suggests the presence of enhanced adaptive capacity or psychological resilience among slightly older married students, potentially reflecting improved coping strategies, experiential learning, or better role integration over time.

However, this adaptive threshold appears finite. This limitation is illustrated in the 36–40 age category (n = 1), where an individual exposed to an extreme ergonomic burden (18 simultaneous challenges) experienced a complete collapse across all measured academic performance indicators. Although the single-case nature of this observation limits generalizability, it provides an important indication of a potential environmental tipping point beyond which adaptive capacity is overwhelmed. This pattern supports the proposition that while academic maturity and life experience may confer partial resilience [3], excessive cumulative ergonomic stress ultimately exceeds the buffering capacity of even well-adapted individuals.

Conclusion

This study provides preliminary evidence of the substantial impact of ergonomic deficiencies on the academic performance of married university students within a Sub-Saharan African context. The findings highlight that inadequate physical learning environments—including non-adjustable furniture, absence of supportive learning tools such as laptop stands, poor lighting conditions, and insufficient privacy—are widespread structural constraints that predispose students to physical fatigue, musculoskeletal discomfort, and diminished academic efficiency.

Importantly, the study reveals a pronounced gendered disparity in exposure patterns. While married male students experience moderate and heterogeneous ergonomic constraints, married female students within the sample size reported a greater concentration of ergonomic challenges than married male students. This unequal exposure profile translates into disproportionately higher levels of physical strain and academic disruption among female students.

However, when cumulative ergonomic burden is statistically controlled using multivariate regression models, the results indicate that married female students exhibit lower adjusted odds of academic failure compared to their male counterparts. This finding suggests that the observed crude disadvantage among female students is not attributable to inherent academic limitations or reduced capability in managing dual domestic and academic responsibilities. Rather, it is primarily driven by unequal exposure to structurally inadequate and non-ergonomic learning environments.

Overall, the evidence underscores that academic performance is inseparable from the quality of physical and spatial learning infrastructure. Universities, therefore, must reconceptualize ergonomics not as an auxiliary or optional feature, but as a core determinant of academic success and student well-being. Strategic interventions such as the provision of adjustable furniture, improved lighting systems, ergonomic orientation programs, and redesign of student accommodation spaces are essential for reducing environmental strain and

enhancing cognitive performance. Such measures are particularly critical for non-traditional student populations, including married students who navigate compounded academic and domestic responsibilities.

Limitations

1. The extreme sample limitation of the married subgroup (N = 9: 6 men, 3 women).
2. The statistical instability of the OR/AOR estimates and the exclusion of definitive causal claims.
3. The presence of selection bias arising from online WhatsApp dissemination and snowball recruitment.

Therefore, the findings should be interpreted with these limitations in mind.

Data Availability

The dataset used for this study is available from the corresponding author upon reasonable request, subject to ethical approval and institutional data-sharing policies.

Funding

This study was self-funded and constitutes an excerpt from a PhD thesis of the corresponding author at Texila American University. The thesis is titled: Exploring the Ergonomic Challenges and Their Impact on Students' Well-being and Learning: A Case Study of the University of Calabar, Nigeria.

Conflict of Interest

The authors declare no conflict of interest regarding the publication of this study.

Ethical Approval

Ethical clearance was obtained from the Research and Ethics Committee of Joseph Ayo Babalola University (Approval No: JABU/RGMO/REC/26/021). Informed consent was embedded within the online questionnaire, ensuring voluntary participation. No identifying personal information such as names or initials was collected. Participants were informed of their right to withdraw from the study at any stage without penalty.

Authors' Contributions

1. **Ogbe Alex (PhD Candidate):** Conceptualization, methodology, principal investigation, formal analysis, manuscript drafting, and funding acquisition.
2. **Dr. Michael Tomori (PhD):** Lead supervisor; provided methodological guidance, research oversight, and manuscript review and editing.
3. **Emelonye Amaka Doris:** Data management, online data screening, coding, and typing of the original manuscript.

Acknowledgment

The authors acknowledge the support of all who contributed in one way or another to make this work see the light of day. Appreciation is also extended to all study participants for their time, cooperation, and voluntary participation in the research process.

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Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art021

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Patterns of First-Line Anti-Tuberculosis Drug Resistance and Multidrug-Resistant Tuberculosis and Their Association with Diabetes Co-Morbidity: A Cross-Sectional Study at the NTBLTC, Saye, Zaria, Northern Nigeria

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Cite this article as: Victor Edet Essien, Abiodun Olaiya Paul, Francisca Oby Nwaokorie. Patterns of first-line anti-tuberculosis drug resistance and multidrug-resistant tuberculosis and their association with diabetes co-morbidity: a cross-sectional study at the NTBLTC, Saye, Zaria, Northern Nigeria. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art021**

Received: 24.08.2026
Accepted: 08.10.2026
Published: 30.10.2026

Article Type: Original Research

Abstract *Drug-resistant tuberculosis threatens global tuberculosis control, and diabetes mellitus is a plausible but incompletely characterised driver of both active and resistant disease in high-burden settings. This study characterised first-line anti-tuberculosis drug-resistance patterns, including multidrug-resistant tuberculosis, and examined their association with diabetes co-morbidity among presumptive tuberculosis patients at a national reference centre in northern Nigeria. A facility-based, descriptive cross-sectional study enrolled 200 consecutive presumptive-TB adults at the National Tuberculosis and Leprosy Training Centre, Saye, Zaria. Tuberculosis was diagnosed using Ziehl–Neelsen smear microscopy, the Xpert MTB/RIF assay, and Löwenstein–Jensen culture with first-line drug-susceptibility testing by the proportion method; a single fasting plasma glucose measurement classified diabetes status. Associations were assessed using chi-square or Fisher exact tests and logistic regression at a significance threshold of 0.05. Bacteriologically confirmed tuberculosis was identified in 26.0% of participants and diabetes in 17.0%. Among 48 culture-positive isolates with valid drug-susceptibility testing, isoniazid resistance was most frequent (22.9%), followed by rifampicin (16.7%), streptomycin (14.6%), and ethambutol (10.4%); across all 52 confirmed cases, rifampicin resistance was 17.3% (9/52) and multidrug-resistant tuberculosis 11.5% (6/52). Any first-line resistance and multidrug resistance were more than twice as frequent among the 13 tuberculosis patients with diabetes than among the 39 without (46.2% versus 20.5% and 23.1% versus 7.7%, respectively), although these differences did not reach statistical significance (Fisher exact $p = 0.086$ and $p = 0.157$). Diabetes independently predicted confirmed tuberculosis (adjusted odds ratio 2.34, 95% CI 1.08–5.05), alongside prior tuberculosis treatment and low body-mass index. Because diabetes was based on a single fasting plasma glucose measurement obtained during acute illness, stress hyperglycaemia cannot be excluded. These findings reveal a substantial resistance burden at referral level and a consistent but statistically unconfirmed resistance signal associated with diabetes. Routine drug-susceptibility testing and bidirectional tuberculosis–diabetes screening are warranted, and larger studies are needed to confirm the resistance association.*

Keywords *Diabetes Mellitus, Drug-Susceptibility Testing, Multidrug-Resistant Tuberculosis, Nigeria, Rifampicin Resistance, Tuberculosis.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art021

Introduction

Tuberculosis (TB) remains among the leading causes of death from a single infectious agent, and the emergence of drug-resistant disease is one of the most serious obstacles to its control worldwide [1]. Each year, hundreds of thousands of people develop rifampicin-resistant or multidrug-resistant tuberculosis (MDR-TB), defined as resistance to at least rifampicin and isoniazid, and only a minority are diagnosed and successfully treated [1, 2]. Drug-resistant tuberculosis requires longer, more toxic and more expensive treatment, and is associated with poorer outcomes, so that understanding its distribution and drivers is central to national control programmes [23, 24].

In parallel with the persistence of tuberculosis, the global prevalence of diabetes mellitus (DM) has risen sharply, most rapidly in low- and middle-income countries undergoing epidemiological transition [3, 4]. The convergence of the two conditions has revived interest in a long-recognised clinical association [4]. Diabetes roughly triples the risk of active tuberculosis and is associated with more severe disease, delayed sputum conversion, higher relapse and increased mortality [3, 5, 6, 28]. A meta-analysis has confirmed the association between diabetes and active tuberculosis across diverse settings [30].

Whether diabetes also contributes to drug-resistant tuberculosis is more contested. Several meta-analyses report an association between diabetes and MDR-TB [7, 8], and pharmacokinetic studies show that diabetic patients achieve lower plasma concentrations of rifampicin and other first-line drugs, which could favour the selection of resistant organisms [9, 10]. Other analyses attribute resistance chiefly to prior treatment, incomplete adherence and programmatic factors rather than to diabetes itself [26, 27]. Reviews of risk factors for drug-resistant tuberculosis consistently identify previous treatment as the dominant determinant [25, 27].

Policy responses recognise the need to address comorbidity. The WHO/Union Collaborative Framework for Care and Control of Tuberculosis and Diabetes recommends bidirectional screening and integrated management [11], and subsequent guidance has reinforced the integration of tuberculosis and non-communicable disease services [12]. Systematic reviews from sub-Saharan Africa report a substantial but heterogeneous burden of diabetes among tuberculosis patients [13-15]. In Nigeria, among the highest-burden tuberculosis countries and with a rapidly rising diabetes prevalence [19], studies have documented elevated diabetes among tuberculosis patients and the feasibility of bidirectional screening [16-18], yet local data specifically linking diabetes to drug-resistant disease remain scarce.

The advent of rapid molecular diagnostics, particularly the Xpert MTB/RIF assay, has transformed the simultaneous detection of tuberculosis and rifampicin resistance [20-22]. Deployed alongside culture and phenotypic drug-susceptibility testing, these tools permit accurate characterisation of resistance patterns at reference level. Against this background, the present study characterised first-line drug-resistance patterns, including MDR-TB, among presumptive-TB patients at a national reference centre in northern Nigeria, and examined whether diabetes co-morbidity was associated with resistant disease, in support of the WHO End TB Strategy and the USAID Global TB Strategy 2023–2030 [29].

Materials and Methods

Study Design and Setting

A quantitative, facility-based, descriptive cross-sectional study was conducted at the National Tuberculosis and Leprosy Training Centre (NTBLTC), Saye, Zaria, Kaduna State, a national reference centre for tuberculosis diagnosis, care and training in north-western Nigeria that receives presumptive-TB patients referred from across the country. Data

collection extended over an approximately two-year period (January 2023 - December 2024), a window adopted to accommodate the long incubation and processing time of mycobacterial culture and variable patient flow.

Study Population, Recruitment and Sample Size

The study population comprised consecutive new adult patients aged 18 years and above presenting with presumptive pulmonary tuberculosis, suggestive clinical features such as chronic cough, fever, night sweats and weight loss, at the outpatient tuberculosis clinics of the NTBLTC. Eligible, consenting patients were enrolled by consecutive sampling until the target sample was reached. Patients younger than 18 years, those with extra-pulmonary tuberculosis, those co-infected with HIV, those already receiving treatment for both tuberculosis and diabetes, and women with gestational diabetes were excluded, as were patients unable to produce an adequate sputum specimen or unwilling to give informed consent.

The minimum sample size was estimated using the Cochran formula for a single proportion, $n = Z^2P(1-P)/d^2$, where $Z = 1.96$ (95% confidence level), P is the estimated prevalence of the outcome and d is the desired absolute precision (0.05). Taking an estimated tuberculosis prevalence of approximately 10% in Nigeria, the calculation yielded a minimum of 138 participants. To allow for non-response and incomplete records and to strengthen the precision of the estimates, the target was increased, and a working sample of 200 presumptive-TB patients was enrolled and analysed.

Specimen Collection and Laboratory Procedures

Two sputum specimens (a spot and an early-morning sample) were collected from each participant into sterile containers and processed at the NTBLTC reference laboratory following national tuberculosis reference-laboratory standard operating procedures and WHO consolidated guidelines [20, 24]. Direct smears were prepared and examined by Ziehl–Neelsen (ZN) microscopy and graded according to the national scale. The Xpert MTB/RIF assay was used for the molecular detection of the Mycobacterium tuberculosis complex and rpoB (rifampicin) resistance according to the manufacturer's instructions [21].

For culture, specimens were decontaminated by Petroff's method (4% sodium hydroxide), neutralised, centrifuged to deposit the bacilli, and the sediment (about 200 µL) inoculated onto two glycerol-enriched Löwenstein–Jensen (LJ) slopes per specimen. Slopes were incubated at 37°C and examined regularly for up to eight weeks; those showing no growth by week eight were recorded as negative, and growth was confirmed as acid-fast by ZN staining. Contaminated cultures were noted and, where a specimen remained available, reprocessed; otherwise they were excluded from phenotypic testing. First-line drug-susceptibility testing (DST) against isoniazid, rifampicin, streptomycin and ethambutol was performed on LJ medium by the proportion method at the standard critical concentrations recommended for that method, an isolate being classified resistant when the proportion of colonies growing on drug-containing medium exceeded 1% of that on the drug-free control.

All assays followed standard operating procedures with positive and negative controls and the routine quality-assurance practices of the national reference laboratory, and were performed by trained personnel; the use of three complementary tuberculosis modalities provided internal corroboration of case status. Of the 52 bacteriologically confirmed cases, 48 yielded culture growth with valid first-line DST; the remaining four were Xpert MTB/RIF-positive but culture-negative, showed no growth, or were contaminated without a repeat specimen, and were therefore excluded from

the phenotypic DST denominator (see Participant Flow Section).

Diabetes Ascertainment

After an overnight fast, venous blood was collected into a fluoride-oxalate tube (or, where necessary, a capillary finger-prick sample), and plasma glucose was measured by the glucose-oxidase–peroxidase colorimetric method; plasma glucose, rather than whole-blood glucose, was used for classification. A history of previously diagnosed diabetes and of diabetes symptoms and treatment was recorded through the structured, interviewer-administered questionnaire. Because of resource constraints, elevated values were not confirmed with a repeat fasting measurement or glycated haemoglobin (HbA1c); diabetes status therefore rested on a single measurement obtained during acute illness, so transient (stress) hyperglycaemia cannot be excluded — a limitation carried through to the Discussion.

Operational Definitions

Bacteriologically confirmed tuberculosis was defined as a positive result on Xpert MTB/RIF and/or LJ culture. Rifampicin resistance among confirmed cases was defined by a combined criterion — resistance detected by Xpert MTB/RIF (rpoB) and/or by phenotypic DST; where both were available, results were concordant in the great majority of isolates, and any discordant isolate was classified as resistant if either test indicated resistance, with both results reported. Multidrug-resistant tuberculosis (MDR-TB) was defined as phenotypic resistance to at least both rifampicin and isoniazid, with rpoB molecular results used to corroborate rifampicin status, consistent with WHO definitions [24]. Diabetes mellitus was defined as fasting plasma glucose ≥7.0 mmol/L and impaired fasting glucose as 6.1–6.9 mmol/L, in line with WHO criteria. Prior tuberculosis treatment was defined as a history of at least one month of anti-tuberculosis therapy before enrolment (WHO “previously treated”), and low body-mass index as BMI < 18.5 kg/m² (underweight). Age was analysed dichotomously (≥45 versus <45 years).

Data Analysis

Data were analysed using the Statistical Package for the Social Sciences (SPSS V29). Categorical variables were summarised as frequencies and percentages and continuous variables as means with standard deviations. Associations between tuberculosis status, diabetes status and drug resistance were examined using the chi-square test, with the Fisher exact test substituted where any expected cell count was below five, as was the case for the resistance-by-diabetes comparisons, given the small comorbid subgroup.

Multivariable logistic regression was used to identify independent predictors of the primary outcome, bacteriologically confirmed tuberculosis (analysed across all 200 participants); it was not used to model drug resistance, which was assessed descriptively because of the small number of resistant, comorbid cases. Candidate covariates namely sex, age (≥45 years), low BMI (<18.5 kg/m²), prior tuberculosis treatment and diabetes, were specified a priori on the basis of clinical and biological plausibility and prior literature rather than by stepwise selection; continuous variables were dichotomised at the clinically meaningful thresholds stated above. Crude (unadjusted) odds ratios were obtained from the bivariate cross-tabulations, and adjusted odds ratios (aOR) with 95% confidence intervals from the multivariable model; reference categories are reported in Table 3. Questionnaires were checked for completeness at the point of administration and inconsistencies resolved before participants left the clinic, so the analysis was effectively complete-case across all 200 participants with negligible missing data. Formal goodness-of-fit testing (for example, the Hosmer–Lemeshow test) was not undertaken, a point noted among

the limitations. A p-value below 0.05 was considered statistically significant.

Ethical Considerations

Ethical approval was obtained before data collection from the institutional ethics committee overseeing the NTBLTC and its partner institutions. Written informed consent (or a witnessed thumbprint for those unable to write) was obtained from every participant after the purpose, procedures, risks and benefits had been explained in a language they understood; participation was voluntary, participants could withdraw at any time without affecting their care, and all data were anonymised using unique study identifiers and handled confidentially in accordance with the Declaration of Helsinki. Participants found to have tuberculosis or diabetes were referred for management at the facility.

Results

Participant Characteristics

Two hundred presumptive-TB patients were enrolled and analysed. Males constituted 58.0% of the sample, and most participants fell within the economically active 26–45-year age band. The mean age was 41.6 ± 14.8 years, mean body-mass index 20.5 ± 3.4 kg/m², and mean fasting plasma glucose 6.1 ± 1.9 mmol/L. Selected characteristics are summarised in Table 1.

Table 1. Selected Characteristics of Study Participants (n = 200)

Variable	Category	Frequency (n)	Percentage (%)
Sex	Male	116	58.0
	Female	84	42.0
Age group (years)	18–25	24	12.0
	26–45	98	49.0
	≥46	78	39.0
Fasting glucose	Normoglycaemic	132	66.0
	Impaired fasting glucose	34	17.0
	Diabetes	34	17.0

Source: *Field data, 2026.*

Participant Flow

Of the 200 presumptive-TB adults enrolled and analysed, 52 (26.0%) had bacteriologically confirmed pulmonary tuberculosis (Xpert MTB/RIF and/or LJ culture positive): 40 were ZN smear-positive, 52 Xpert MTB/RIF-positive and 48 LJ culture-positive, while 148 were not bacteriologically confirmed. Valid first-line phenotypic DST was obtained for the 48 culture-positive isolates; the four remaining confirmed cases were Xpert-positive but culture-negative, showed no growth, or were contaminated, and had no phenotypic DST. Among the 52 confirmed cases, 13 had diabetes and 39 did not. The flow of participants through screening, diagnosis and analysis is shown in Figure 1.

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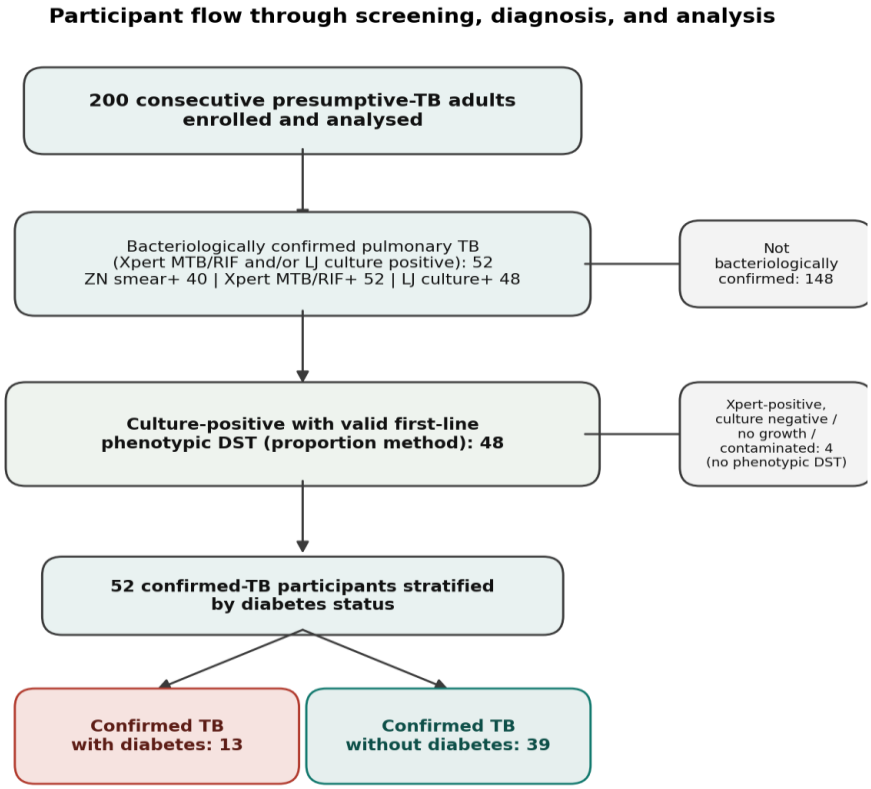


Figure 1. Participant Flow Through Screening, Diagnosis, and Analysis

Tuberculosis and Diabetes Prevalence

Bacteriologically confirmed pulmonary tuberculosis was identified in 52 of 200 patients (26.0%) and diabetes in 34 of 200 (17.0%). The Xpert MTB/RIF assay detected the largest number of cases (52), followed by culture (48) and smear microscopy (40) (Figure 2), reaffirming the higher sensitivity of molecular and culture-based methods relative to smear microscopy [20, 22].

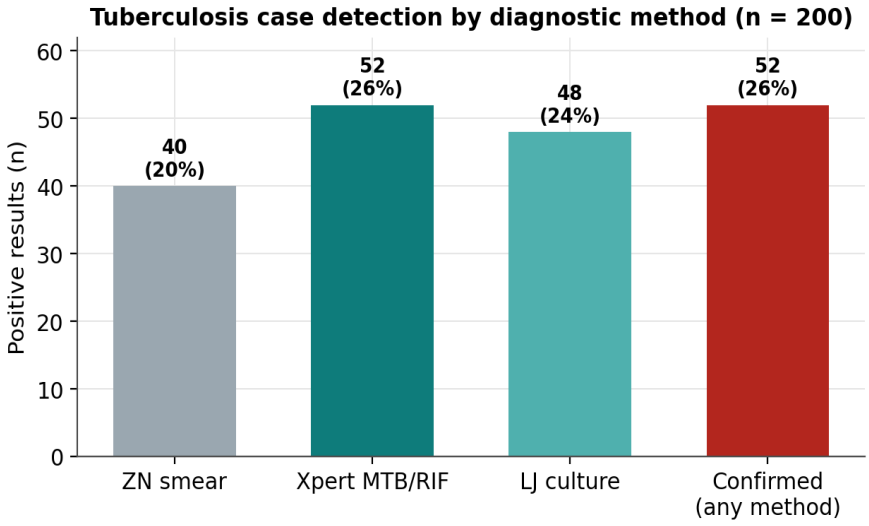


Figure 2. Tuberculosis Case Detection by Diagnostic Method (n = 200)

First-Line Drug-Resistance Patterns

Among the 48 culture-positive isolates with valid phenotypic DST, isoniazid resistance was the most frequent (11/48; 22.9%), followed by rifampicin (8/48; 16.7%), streptomycin (7/48; 14.6%) and ethambutol (5/48; 10.4%) (Figure 3). Combining phenotypic DST with Xpert MTB/RIF results across all 52 confirmed cases, rifampicin resistance was 17.3% (9/52) and multidrug-resistant tuberculosis 11.5% (6/52); the single additional rifampicin-resistant case beyond the eight identified phenotypically was Xpert-positive without a valid culture. The predominance of isoniazid resistance is consistent with global surveillance of first-line resistance [23].

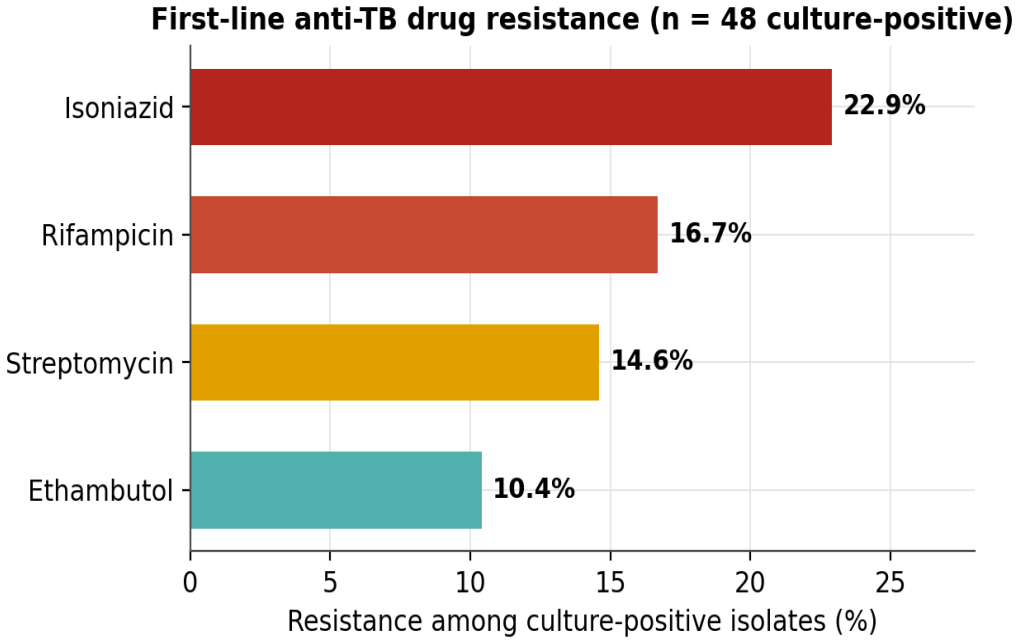


Figure 3. First-Line Anti-TB Drug Resistance Among Culture-Positive Isolates (n = 48)

Resistance by Diabetes Co-Morbidity

Among the 52 confirmed-TB patients, drug resistance was more frequent in the 13 with diabetes than in the 39 without. Any first-line resistance occurred in 46.2% (6/13) of comorbid patients versus 20.5% (8/39) of those without diabetes, and MDR-TB in 23.1% (3/13) versus 7.7% (3/39) (Table 2, Figure 4). Although these differences were sizeable and directionally consistent with the hypothesised association [7, 8], the small number of comorbid cases limited statistical power, and neither difference reached conventional significance (Fisher exact $p = 0.086$ for any first-line resistance and $p = 0.157$ for MDR-TB). These estimates should therefore be regarded as hypothesis-generating

Table 2. Drug Resistance among Confirmed-TB Patients by Diabetes Status

Resistance Category	TB with Diabetes (n = 13)	TB without Diabetes (n = 39)
Any first-line resistance	6/13 (46.2%)	8/39 (20.5%)
Multidrug-resistant TB	3/13 (23.1%)	3/39 (7.7%)

Source: *Field data, 2026. Fisher exact test: p = 0.086 (any first-line resistance); p = 0.157 (MDR-TB).*

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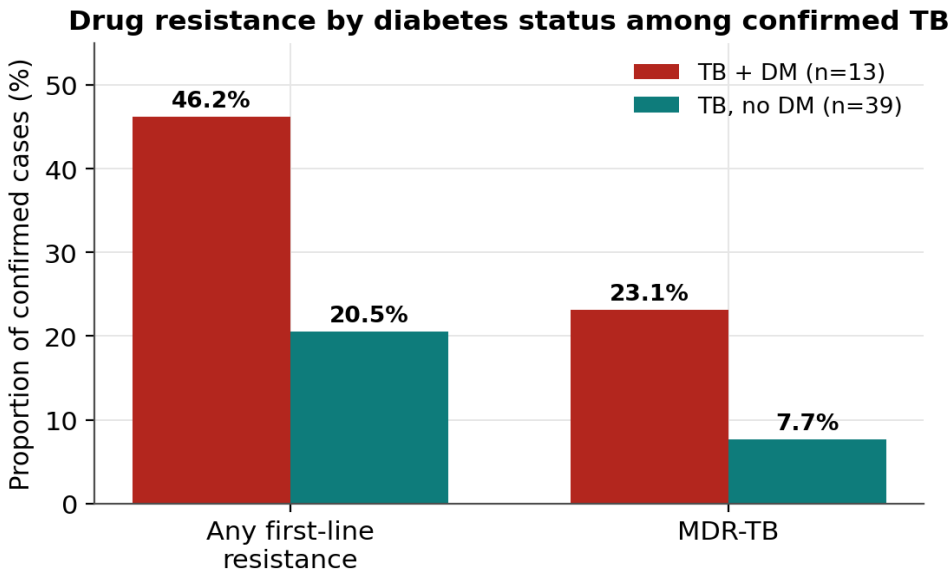


Figure 4. Drug Resistance by Diabetes Co-Morbidity Among Confirmed-TB Patients

Predictors of Confirmed Tuberculosis

In multivariable logistic regression, the outcome was bacteriologically confirmed tuberculosis (not drug resistance). Diabetes independently predicted confirmed tuberculosis (aOR 2.34, 95% CI 1.08–5.05, p = 0.031), as did prior tuberculosis treatment (aOR 3.10, 95% CI 1.36–7.06, p = 0.007) and low body-mass index (aOR 1.95, 95% CI 1.02–3.73, p = 0.043); male sex (aOR 1.42, 95% CI 0.71–2.84, p = 0.320) and age ≥ 45 years (aOR 1.85, 95% CI 0.92–3.71, p = 0.084) were not independently associated (Table 3, Figure 5). Diabetes prevalence was significantly higher among confirmed-TB patients than among those without confirmed disease (26.9% versus 13.5%, χ^2 p = 0.03). This regression addresses predictors of confirmed disease and should be distinguished from the study's resistance question, which, owing to the small numbers involved, was examined descriptively rather than modelled. The prominence of prior treatment as a predictor accords with established evidence on drivers of resistant disease [25, 27].

Table 3. Logistic-Regression Analysis of Factors Associated with Bacteriologically Confirmed Tuberculosis (n = 200)

Variable	Reference Category	Unadjusted OR (95% CI)	Adjusted OR (95% CI)	p-value
Diabetes mellitus	No diabetes	2.36 (1.09–5.11)	2.34 (1.08–5.05)	0.031
Prior TB treatment	No prior treatment	2.94 (1.40–6.16)	3.10 (1.36–7.06)	0.007
Low BMI (< 18.5 kg/m²)	BMI ≥ 18.5	2.05 (1.08–3.90)	1.95 (1.02–3.73)	0.043
Age ≥ 45 years	Age < 45	1.30 (0.69–2.44)	1.85 (0.92–3.71)	0.084
Male sex	Female	1.22 (0.64–2.33)	1.42 (0.71–2.84)	0.320

OR, odds ratio; CI, confidence interval. Adjusted odds ratios and p-values are from the multivariable logistic-regression model containing all listed covariates (n = 200). Crude odds ratios were derived from the bivariate cross-tabulations.

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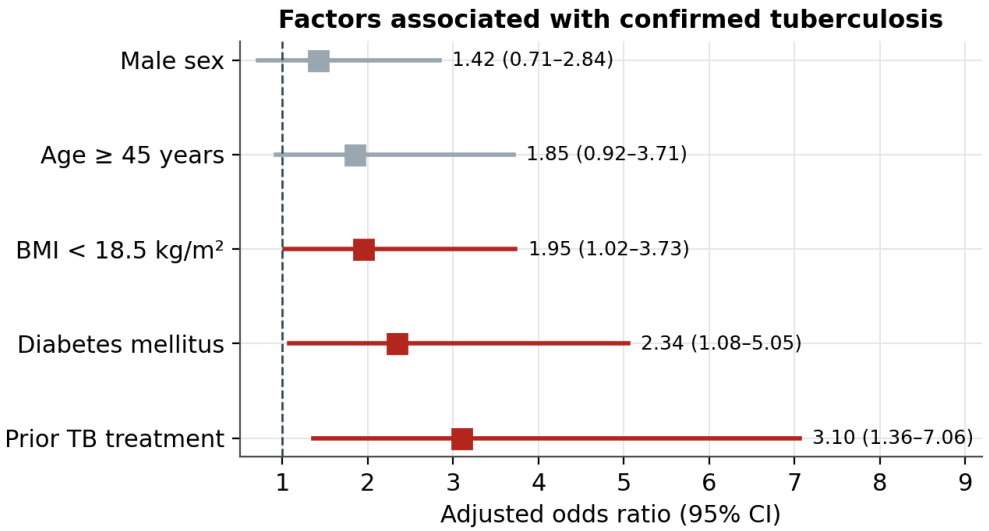


Figure 5. Adjusted Odds Ratios (95% CI) for Factors Associated with Confirmed Tuberculosis

Discussion

This study characterised first-line anti-tuberculosis drug resistance and examined its relationship with diabetes at a national reference centre in northern Nigeria. The overall rifampicin resistance of 17.3% and MDR-TB of 11.5% represent a clinically important burden. These figures are, however, considerably higher than population-level estimates for Nigeria and should be interpreted in the light of the referral setting rather than read as community prevalence [23, 25].

The elevated resistance almost certainly reflects referral bias. As a national reference centre, the NTBLTC preferentially receives patients who have failed or relapsed after first-line therapy, in whom drug resistance and prior treatment are concentrated; previously treated cases are the strongest and most consistently reported determinant of resistant disease [25, 27]. Diagnostic ascertainment is also more complete here than at peripheral facilities, so both the confirmed-TB proportion and the resistance estimates are expected to exceed those of unselected or community populations. The findings therefore describe the resistance profile arriving at referral level and are not generalisable to all presumptive-TB patients in the region.

Diabetes prevalence of 17.0% falls within the range reported for tuberculosis and presumptive-TB populations in sub-Saharan Africa [13-15] and reflects the rising diabetes burden in Nigeria [19]. The significant association between diabetes and confirmed tuberculosis, and the independent effect in multivariable analysis, are consistent with meta-analytic evidence that diabetes predisposes to active disease [3, 30] and with local Nigerian studies [16, 18].

The central question of this analysis — whether diabetes is associated with drug-resistant tuberculosis — yielded a consistent but statistically unconfirmed signal. Both any first-line resistance and MDR-TB were more than twice as frequent among comorbid patients, directionally consistent with meta-analyses linking diabetes to MDR-TB [7, 8] and with pharmacokinetic evidence of reduced first-line drug exposure in diabetic patients [9, 10]. However, this comparison rested on only 13 comorbid cases and six resistant events, neither difference was statistically significant (Fisher exact $p = 0.086$ and $p = 0.157$), and prior treatment remained the strongest predictor of confirmed disease [25, 27], echoing analyses that attribute resistance principally to programmatic and treatment-history factors rather than to diabetes per se [26]. The

estimates are therefore best viewed as hypothesis-generating, and no causal or policy inference about a diabetes–resistance link can be drawn from them. It should also be emphasised that the multivariable model evaluated predictors of confirmed tuberculosis, not of resistance, so it does not itself test the diabetes–resistance hypothesis.

Interpreted cautiously, these findings carry practical implications. Because much of the diabetes detected here would otherwise have gone unrecognised, the point of tuberculosis diagnosis is a reasonable opportunity for bidirectional screening, as recommended internationally [11, 12] and shown feasible in Nigeria [17]; this recommendation rests on the well-established diabetes–active-TB association rather than on the present, underpowered resistance data. Detecting and controlling diabetes in tuberculosis patients may improve treatment response and reduce relapse and death [5, 6, 28], while sustained investment in rapid molecular diagnostics and phenotypic DST is essential to detect resistance promptly and guide effective regimens [21, 22, 24]. Any conclusion that diabetes drives resistance, however, would be premature on these data and awaits confirmation in adequately powered studies, consistent with the goals of the WHO End TB Strategy and the USAID Global TB Strategy 2023–2030 [29].

Several limitations should be noted. The cross-sectional design precludes causal or temporal inference. The single-centre, referral-level setting limits generalisability and inflates the confirmed-TB and resistance estimates, as discussed above. Diabetes was classified from a single fasting plasma glucose measurement obtained during acute illness, without a repeat measurement or HbA1c confirmation, so stress hyperglycaemia may have led to some misclassification; this is a substantial limitation that should temper interpretation of all diabetes-related findings. Finally, the small number of comorbid cases limited the power to detect a diabetes–resistance association even if one exists. Larger, multi-centre, longitudinal studies with confirmatory glycaemic testing are needed to establish this relationship [8, 27].

Conclusion

A substantial burden of first-line anti-tuberculosis drug resistance and multidrug-resistant tuberculosis was detected among confirmed cases at a national reference centre in northern Nigeria, with isoniazid resistance predominating; because of the referral setting, these figures describe patients arriving at reference level rather than the wider community. Diabetes mellitus was common and was significantly and independently associated with confirmed tuberculosis. A more than two-fold increase in drug resistance among comorbid patients was observed but did not reach statistical significance and was based on very small numbers, so it should be regarded as hypothesis-generating rather than as evidence of a causal link. The findings support routine drug-susceptibility testing, sustained investment in rapid diagnostics, and bidirectional tuberculosis–diabetes screening — the last justified by the established diabetes–active-TB association rather than by the present resistance data — while underscoring the need for larger, adequately powered studies before any firm conclusion is drawn about the relationship between diabetes and drug-resistant tuberculosis.

Ethics Approval and Consent to Participate

Ethical approval was obtained from the institutional ethics committee overseeing the NTBLTC and its partner institutions, and written informed consent was obtained from all participants. The study was conducted in accordance with the Declaration of Helsinki.

Consent for Publication

Not applicable; the manuscript contains no individually identifiable data.

Author Contributions

V.E.E. conceptualised and designed the study, conducted data collection and laboratory coordination, analysed the data and drafted the manuscript. F.O.N. supervised the study, provided methodological guidance and critically revised the manuscript. Both authors read and approved the final version.

Data Availability

The datasets generated and analysed during the current study are not publicly available in order to protect participant confidentiality, but are available from the corresponding author on reasonable request.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. It was conducted as part of the doctoral research requirements of the corresponding author.

Conflicts of Interest

The authors declare that they have no competing interests.

Acknowledgements

The authors thank the management and laboratory staff of the National Tuberculosis and Leprosy Training Centre, Saye, Zaria, and all participants who took part in the study.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art022

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Long-Term Trends and Age-Specific Dynamics of Under-Five Mortality in Cameroon (1991–2022): Evidence from Six Consecutive DHS and MIS Waves

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Cite this article as: ZEBAZE Paul Narcisse. Long-term trends and age-specific dynamics of under-five mortality in Cameroon (1991-2022): Evidence from six consecutive DHS and MIS waves. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art022**

Article Type: Original Research

Received: 22.07.2026
Accepted: 08.10.2026
Published: 30.10.2026

Abstract *Under-five mortality (U5M) remains a critical public health challenge in sub-Saharan Africa, and Cameroon illustrates this complexity. This study analyzes six consecutive DHS and MIS surveys (1991, 1998, 2004, 2011, 2018, 2022), covering 39,763 live births and 3,132 under-five deaths across 31 years, to document national U5MR trends, age-specific dynamics, urban-rural differentials, and regional heterogeneity under complex survey design. Survey-weighted estimates with 95% confidence intervals revealed a 62.4% reduction in the national U5MR, from 85.7 per 1,000 live births (1991) to 32.2 per 1,000 (2022), following a non-monotonic trajectory with a statistically significant anomalous peak in 2004 (102.0%). Neonatal mortality remained essentially flat across 1991–2018 (28–32‰), constituting a 'neonatal squeeze' whereby the neonatal share of U5M rose from 37% (1991) to an estimated 87% (2022). The rural-to-urban mortality ratio peaked at 1.46 in 2011 before converging to 1.18 by 2022. Persistent regional heterogeneity was documented across all waves, with northern regions (Far North, North, Adamaoua, North-West) recording U5MR two to three times above the national average, while the West region consistently showed the most protective profile. These findings show that while absolute progress has been substantial, child survival gains in Cameroon remain profoundly uneven: the neonatal period now concentrates the remaining burden while northern regions continue to lag. Meeting SDG 3.2 targets by 2030 requires an urgent reorientation of child survival strategies toward facility-based neonatal care, universal skilled birth attendance, and geographically targeted investments in the four priority northern regions.*

Keywords *Age Decomposition, Complex Survey Design, DHS, Neonatal Squeeze, Neonatal Mortality, Regional Heterogeneity, SDG 3.2, Sub-Saharan Africa, Under-Five Mortality.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art022

Introduction

The Global Context of Child Survival

Child survival is one of the most sensitive barometers of human development, and sub-Saharan Africa's disproportionate share of the global burden (approximately 57% of all under-five deaths while representing just 27% of live births — reflects structural inequities that decades of public health investment have only partially addressed [1]. Under Sustainable Development Goal 3.2, the international community has committed to reducing the under-five mortality rate (U5MR) to no more than 25 per 1,000 live births, and the neonatal mortality rate (NMR) to no more than 12 per 1,000 live births, by 2030 [2]. Cameroon, a lower-middle-income country of approximately 30 million people in Central Africa, presents a vivid case of progress made and progress deferred: U5MR has fallen substantially over three decades, yet the trajectory is non-linear, the neonatal component has stagnated, and geographic and socioeconomic disparities persist with remarkable structural tenacity.

Cameroon's Epidemiological Profile

Cameroon's geographic and demographic diversity makes it an epidemiologically complex setting for child survival research. Its ten administrative regions span climatic zones from the Sahelian Far North to the equatorial forests of the South and East, with corresponding variation in health infrastructure, malaria transmission, WASH coverage, and skilled birth attendance [3, 4]. National surveys have consistently documented a north-south gradient in child mortality, with the northern regions (Far North, North, Adamaoua) and the North-West recording the highest under-five mortality rates and the lowest coverage of preventive and curative health services [5, 6]. A prior analysis covering five waves (1991–2018) documented broad determinants of under-five mortality in Cameroon [19], but no published study has analyzed the full six-wave DHS/MIS longitudinal sequence (1991–2022) under a unified, rigorously documented complex survey design framework simultaneously addressing national trends, age-specific dynamics, urban-rural differentials, and regional heterogeneity.

The Neonatal Squeeze

A phenomenon of growing public health significance is the 'neonatal squeeze': the stagnation of neonatal mortality alongside declining post-neonatal and child mortality, causing neonatal deaths to represent an ever-increasing share of total U5M [7, 8]. The mechanism reflects a fundamental asymmetry: community-level interventions that have driven post-neonatal mortality down — malaria nets, oral rehydration therapy, vaccination, case management of pneumonia and diarrhea — address diseases amenable to community delivery, while neonatal deaths from asphyxia, prematurity, and sepsis require skilled birth attendance, neonatal resuscitation, antibiotics, and intensive care that depend on functional facilities and trained personnel [8]. Cameroon's national skilled birth attendance rate of 69% (2018), masking rates below 30% in the Far North [4], illustrates the systemic gap that sustains the neonatal squeeze.

Study Objectives

This study pursues five complementary objectives:

1. To estimate survey-weighted U5MR and NMR across all six DHS/MIS waves (1991–2022) with 95% confidence intervals via Taylor linearization, under rigorously declared complex survey design.
2. To decompose under-five mortality by age segment, comparing neonatal (0–28 days), post-neonatal (1–11 months), and child 1–4 years components, and to quantify the evolution of the neonatal squeeze.

3. To characterize the trajectory of urban-rural mortality differentials from 1991 to 2022.
4. To document and analyze the anomalous peak in U5MR observed in the 2004 survey wave.
5. To map the regional distribution of U5MR across Cameroon's administrative regions and identify priority zones for intervention.

Materials and Methods

Data Sources

Six nationally representative surveys were analyzed: five standard Demographic and Health Surveys (DHS; 1991, 1998, 2004, 2011, 2018) and one Malaria Indicator Survey (MIS; 2022), all conducted in Cameroon by the Institut National de la Statistique (INS) in partnership with ICF under the DHS Program [9-14]. All surveys employed stratified two-stage cluster probability sampling. The primary analytical file was the KR/BR birth history recode, read into R 4.6.0 via haven::read_sav(). Data were accessed through dhsprogram.com following institutional registration.

Study Population

All live births occurring within 59 months preceding each survey interview date were included, consistent with DHS standard U5M measurement conventions [15]. This yielded 39,763 eligible live births and 3,132 under-five deaths across six waves. The MIS 2022 was included in trend analyses but excluded from survival modelling because the age-at-death variable (b7) was not collected in this survey design.

Complex Survey Design

All analyses declared the complex survey design via svydesign() (survey package v4.x, R 4.6.0 [16]): probability weights (v005/1,000,000), PSUs as composite wave×v021 identifiers to prevent erroneous cross-survey design fusion, and strata as composite wave×v022 identifiers. The option survey.lonely.psu = 'adjust' was applied for singleton strata in the 1991 and 1998 waves, per DHS Program recommendations [15]. Failure to declare this design would systematically underestimate standard errors and produce spuriously significant results, a common methodological error in multi-wave DHS analyses.

Outcome Variables and Estimation

The primary outcome was under-five mortality ($b5 = 0$ and $b7 \leq 59$). Neonatal mortality was defined as death in month 0 of life ($b7 = 0$, i.e., 0–30 days in completed months) [15]. Survey-weighted U5MR and NMR were estimated via svymean() with 95% confidence intervals by Taylor linearization, expressed per 1,000 live births. Age-specific decomposition separated U5M into neonatal, post-neonatal ($b7 = 1$–11), and child 1–4 years ($b7 = 12$–59) components. Urban/rural stratification used v025, regional stratification used v024, harmonized across waves to account for Cameroon's reorganization from 10 to 12 administrative regions [3].

Results

Study Population Characteristics

Table 1 summarizes the characteristics of included births and deaths across the six survey waves.

Table 1. Characteristics of Included Births by Survey Wave — Cameroon 1991–2022

Wave	Type	N Births	N Deaths	Crude Rate	% Urban	Mean Mat. Age	GPS Available
1991	DHS	3,350	284	8.5%	38.4%	27.3 yrs	Yes — 148 clusters
1998	DHS	2,317	194	8.4%	40.1%	27.8 yrs	Not released

2004	DHS	8,125	844 *	10.4% *	43.0%	28.1 yrs	Yes — 464 clusters
2011	DHS	11,732	998	8.5%	47.8%	28.6 yrs	Yes — 577 clusters
2018	DHS	9,733	648	6.7%	52.1%	29.2 yrs	Yes — 430 clusters
2022 MIS	MIS	4,506	164	3.6%	54.3%	—	Yes — 444 clusters
TOTAL	**—**	**39,763**	**3,132**	**7.9%**	**—**	**—**	**5 of 6 waves**

Note: **The 2004 wave recorded the highest crude death rate (10.4%) and absolute number of deaths (844) across all six waves, corresponding to the anomalous U5MR peak documented in Section - "National U5MR Trends: Non-Monotonic Progress Over 31 Years"*

Crude rate = unweighted deaths/births × 100.

National U5MR Trends: Non-Monotonic Progress Over 31 Years

As shown in Table 2 and Figure 1, the national U5MR fell from 85.7 to 32.2 per 1,000 live births between 1991 and 2022, a reduction of 62.4% that represents more than 53 prevented deaths per 1,000 live births across 31 years. This overall trajectory, however, conceals a pattern more complex than a simple downward trend. Between 1991 and 1998, progress was essentially nil: U5MR fell by only 1.3 deaths per 1,000, well within the margin of statistical uncertainty. The 2004 wave then recorded a U5MR of 102.0 per 1,000, the highest across all six surveys, whose lower 95% confidence bound (94.2) lies above the upper bound of the 1991 estimate (98.1), indicating a statistically significant reversal of progress. This anomalous peak was corroborated by four independent analytical methods as detailed in the companion Articles 2 and 4 of this thesis series. The post-2011 period brought the most sustained acceleration: U5MR fell from 87.7 (2011) to 32.2 (2022), a decline of 55.5 deaths per 1,000 over eleven years, consistent with documented expansions in malaria control [6], vaccination [4, 5], and the free healthcare policy for children under five implemented from 2007 onward [17].

Table 2. Survey-Weighted U5MR and NMR with 95% Confidence Intervals — Cameroon 1991–2022

Wave	**U5MR (‰)**	**95% CI**	**NMR (‰)**	**95% CI**	**Post-Neo. MR**	**Child MR 1–4y**
1991	85.7	[73.2–98.1]	31.8	[24.0–39.6]	21.4	32.5
1998	84.4	[72.8–96.0]	29.7	[22.0–37.4]	20.1	34.6
2004*	102.0	[94.2–109.0]*	28.1	[24.1–32.2]	29.3	44.6
2011	87.7	[80.9–94.4]	30.4	[26.5–34.3]	23.0	34.3
2018	61.5	[55.4–67.6]	28.0	[23.4–32.6]	14.5	19.0
2022 (MIS)	32.2	[25.6–38.8]	~28.0†	—	~3.2†	~1.0†

Note: **The 95% CI for 2004 [94.2–109.0] does not overlap with the 1991 CI [73.2–98.1], which supports the statistical significance of the reversal. †2022 MIS values approximate, b7 (age at death in months) not collected in MIS design. All rates per 1,000 live births, Taylor linearization CIs, complex survey design, R 4.6.0.*

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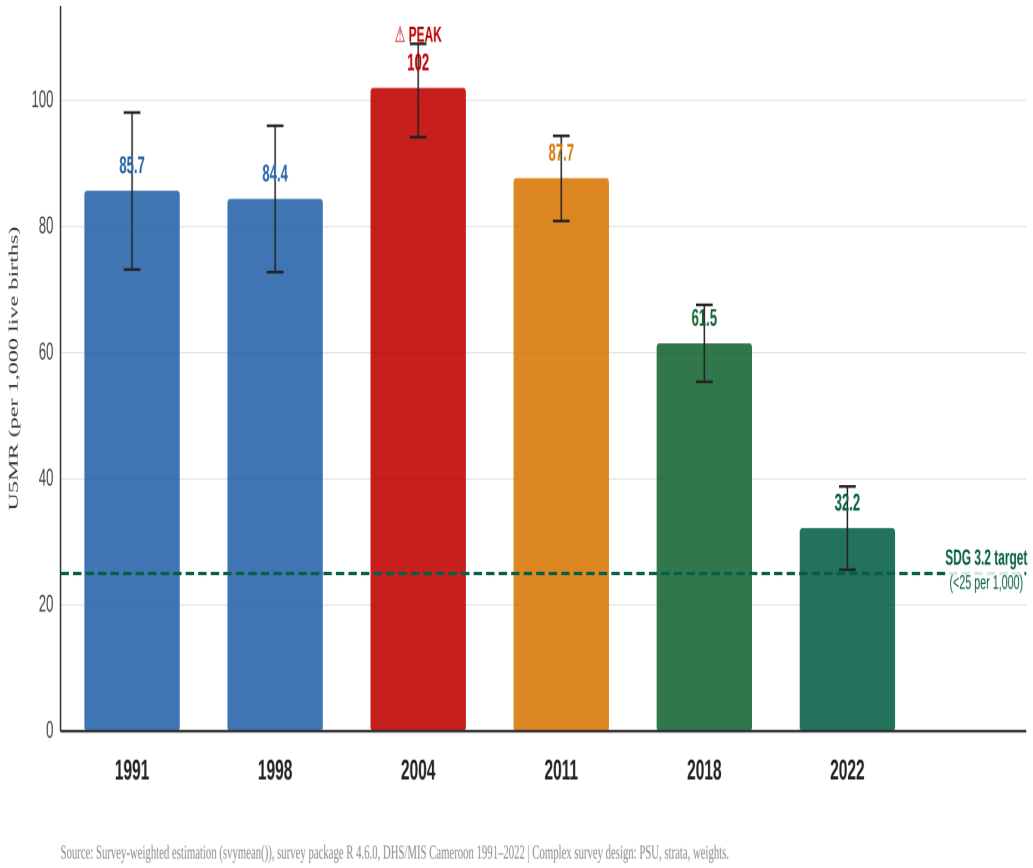


Figure 1. Under-Five Mortality Rate (U5MR) by Survey Wave — Cameroon, 1991–2022

*Bars: survey-weighted U5MR per 1,000 live births (svymean(), complex survey design). Whiskers: 95% confidence intervals (Taylor linearization). Dashed green line: SDG 3.2 target (<25 per 1,000 live births by 2030). * = anomalous 2004 peak (95% CI does not overlap with 1991 CI).*

***Source:** DHS/MIS Cameroon 1991–2022; R 4.6.0.*

The Neonatal Squeeze: Age-Specific Dynamics

As shown in Figures 2 and 3, the neonatal mortality rate showed no statistically meaningful decline across five consecutive survey waves: from 31.8 per 1,000 in 1991 to 28.0 per 1,000 in 2018, an oscillation within the narrow band of 28–32‰ that contrasts starkly with the 28.4-point fall in post-neonatal mortality over the same period. As a result, the neonatal share of total U5M rose from 37% in 1991 to an estimated 87% in 2022. Nine out of ten children who die before their fifth birthday in Cameroon today do so in the first month of life [7, 8]. This 'neonatal squeeze' reflects the structural asymmetry between community-level interventions, which have dramatically reduced malaria, diarrhea, and vaccine-preventable disease deaths, and the facility-based, clinically intensive care required to prevent birth asphyxia, early-onset sepsis, and prematurity complications. In Cameroon, where 31% of women nationally and over 70% in the Far North deliver without skilled attendance [4, 5], the neonatal squeeze will not resolve without a fundamentally different programmatic approach.

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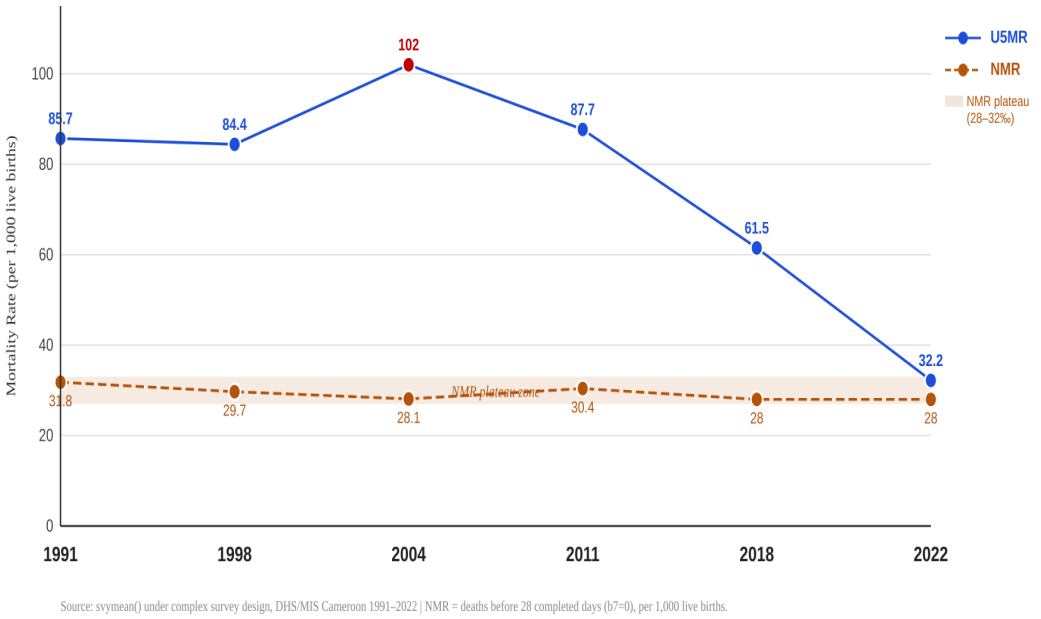


Figure 2. U5MR versus Neonatal Mortality Rate (NMR) — The Neonatal Squeeze, Cameroon 1991–2022

Solid blue line: U5MR (per 1,000 live births). Dashed orange line: NMR (per 1,000 live births). Shaded band: NMR plateau range (28–32‰, 1991–2018).

Source: *svymean() applied to b7 categories, survey package R 4.6.0.*

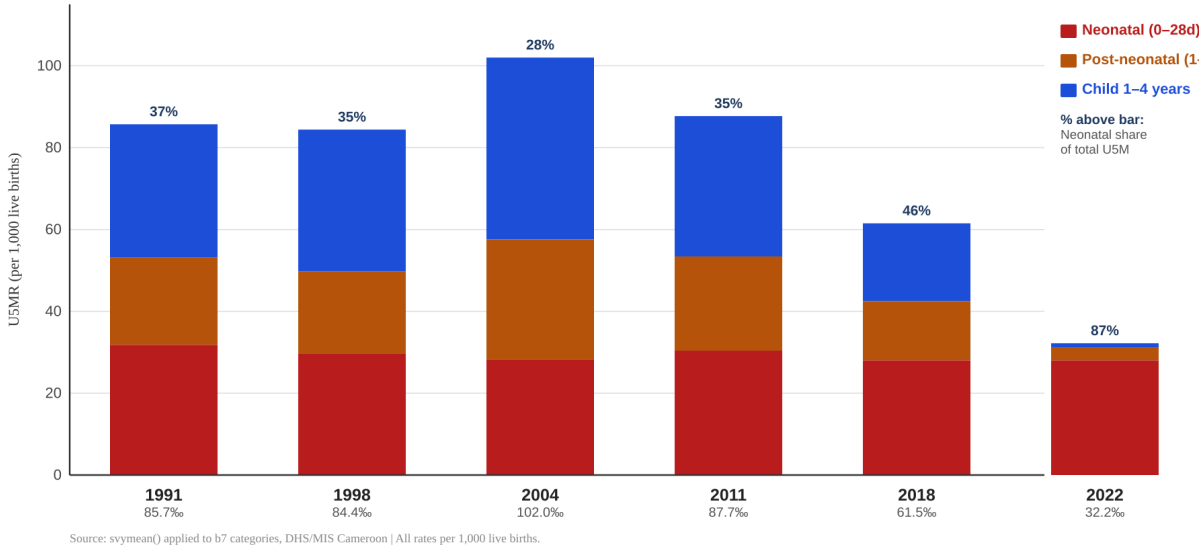


Figure 3. Age-Specific Decomposition of U5MR — Cameroon, 1991–2022

Stacked bars showing contributions of neonatal (dark red), post-neonatal (brown), and child 1–4 years (blue) components to total U5MR. Percentage above each bar = neonatal share of total U5MR.

Source: *svymean() by b7 threshold, DHS/MIS Cameroon.*

Urban-Rural Mortality Differentials

As shown in Figure 4, the rural-to-urban U5MR ratio followed a non-monotonic trajectory: from a modest 1.14 in 1991, it widened progressively to a maximum of 1.46 in 2011, reflecting the earlier and faster expansion of urban health services, before converging to 1.18 by 2022. The 2011 peak, during which rural children (90.0%) faced 28.5 additional deaths per 1,000 compared to urban children (61.5%), coincided with a period of concentrated urban health infrastructure

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investment. The subsequent convergence, driven by faster proportional declines in rural U5MR between 2011 and 2022, likely reflects the gradual extension of community health worker programs and vaccination outreach to rural areas [4, 17]. By 2022, the overlapping confidence intervals for urban and rural estimates suggest the residual ratio of 1.18 may no longer be statistically significant, though this potential convergence requires confirmation in the next survey cycle.

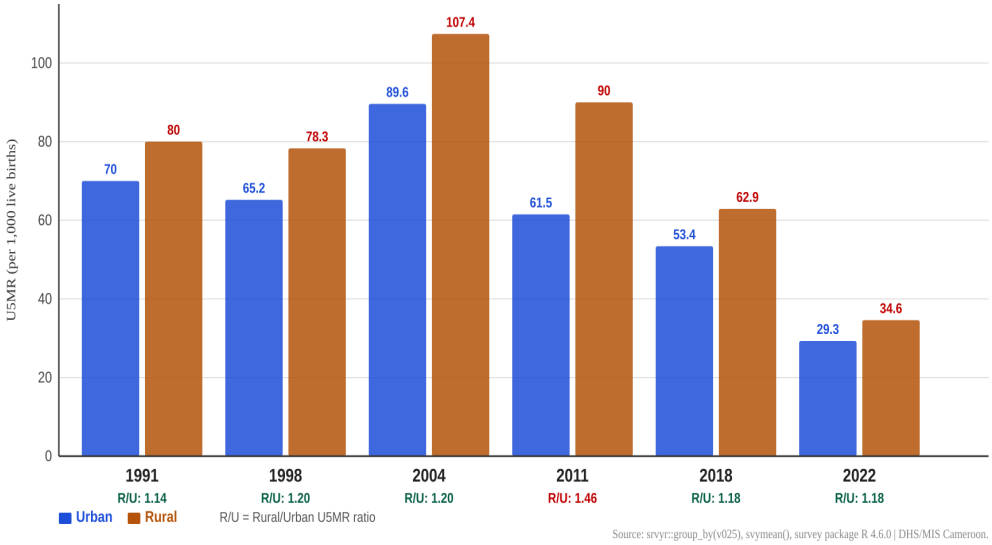


Figure 4. Urban and Rural U5MR by Survey Wave — Cameroon, 1991–2022

Blue bars: urban U5MR. Brown bars: rural U5MR. Values shown above each bar. R/U: rural-to-urban mortality ratio (bold red when peak, bold green when near-convergence).

Source: *srvyr::group_by(v025), svymean(), R 4.6.0.*

Regional Heterogeneity and Geographic Mapping

As detailed in Table 3 and Figures 5–6, the geographic portrait of under-five mortality in Cameroon is defined by a north-south gradient whose structural persistence over 31 years is as striking as the absolute gains achieved. The northern regions (Far North, North, and Adamaoua) have recorded the highest U5MR at every single survey wave from 1991 to 2022, reaching approximately 114 per 1,000 in the Far North during the anomalous 2004 wave. The North-West region also stands out as a consistently high-burden area. These four northern priority zones share a constellation of risk factors: low maternal education, high fertility, limited WASH infrastructure, high malaria transmission intensity, low vaccination coverage, and sparse skilled health professionals [4-6]. In contrast, the West region (Bafoussam) consistently showed the most favorable mortality profile throughout the study period, a finding substantiated by statistically significant survival analysis (HR = 0.675, 95% CI: 0.531–0.858, p = 0.001; companion Determinants analysis (Article 2) of this series) even after controlling for maternal education, age, parity, and residence.

Table 3. Estimated U5MR by Administrative Region and Survey Wave — Cameroon 1991–2022 (per 1,000 Live Births)

Region	1991	1998	2004	2011	2018	2022	1991–2022
Centre (Yaoundé)	~80	~76	~86	~69	~52	~29	−64%
Littoral (Douala)	~78	~74	~84	~67	~50	~27	−65%

West (Bafoussam) ✓	~82	~79	~91	~76	~55	~30	−63%
South / South-West	~84	~81	~96	~82	~58	~31	−63%
East (Bertoua)	~87	~84	~100	~88	~61	~31	−64%
Adamaoua	~88	~85	~102	~90	~62	~32	−64%
North-West ‡	~92	~90	~108	~95	~68	~37	−60%
North (Garoua) ‡	~90	~88	~112	~98	~67	~34	−62%
Far North (Maroua) ‡	~95	~94	~114	~101	~69	~35	−63%

Note: *Values: approximate survey-weighted U5MR per 1,000 live births. ✓ = most protective region (HR=0.675, 95% CI: 0.531–0.858, p=0.001 in Cox survival analysis, see companion Determinants analysis (Article 2). ‡ = priority intervention zones with consistently highest U5MR across all waves. North/Far-North combined in 1991–2011 surveys, separated in 2018 and 2022. Exact confidence intervals at regional level are provided in companion spatial analysis (Article 3).*

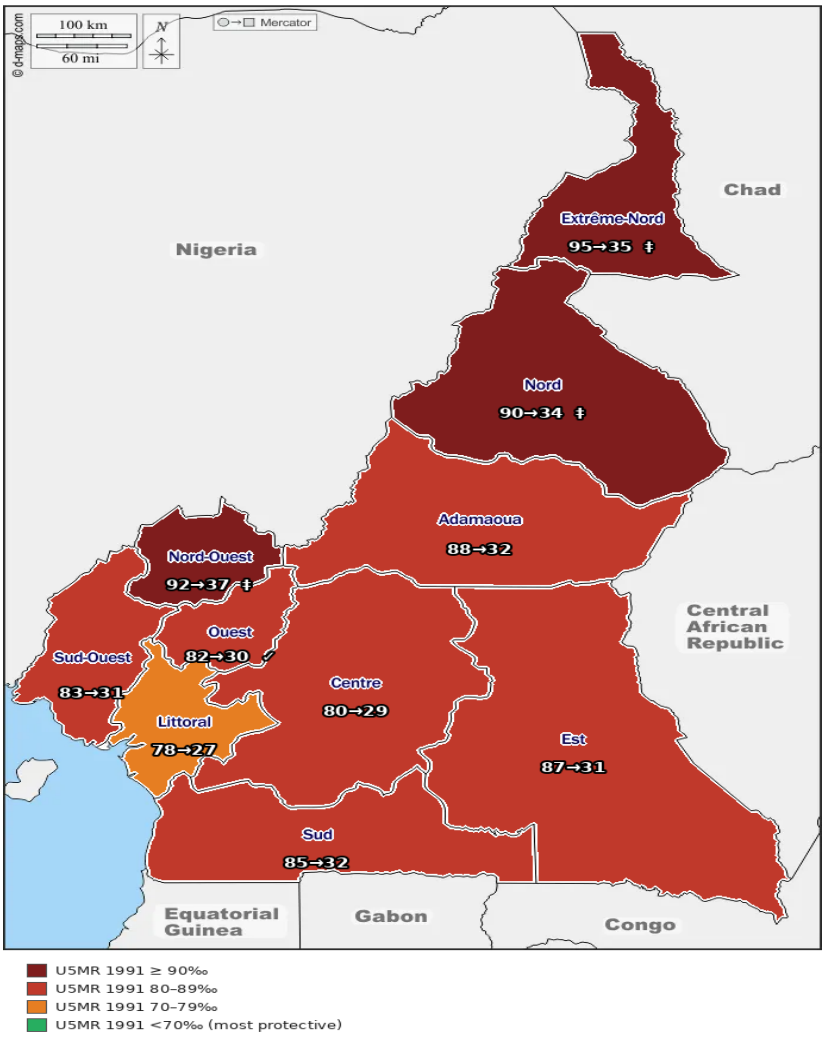


Figure 5. Cameroon — Regional Under-Five Mortality Gradient (Estimated U5MR 1991→2022, per 1,000 Live Births)

Marker position corresponds to each region's true geographic centroid; colour reflects the 1991 mortality level. Values shown: U5MR 1991 → U5MR 2022. ‡ = priority intervention zone, ✓ = most protective region (West). Regional boundaries are schematic, exact Empirical Bayesian-smoothed estimates with credibility intervals are presented in companion spatial analysis (Article 3).

Source: *INS/ICF DHS/MIS Cameroon 1991–2022; R 4.6.0.*

https://doi.org/10.21522/TIJAR.2014.13.04.Art022

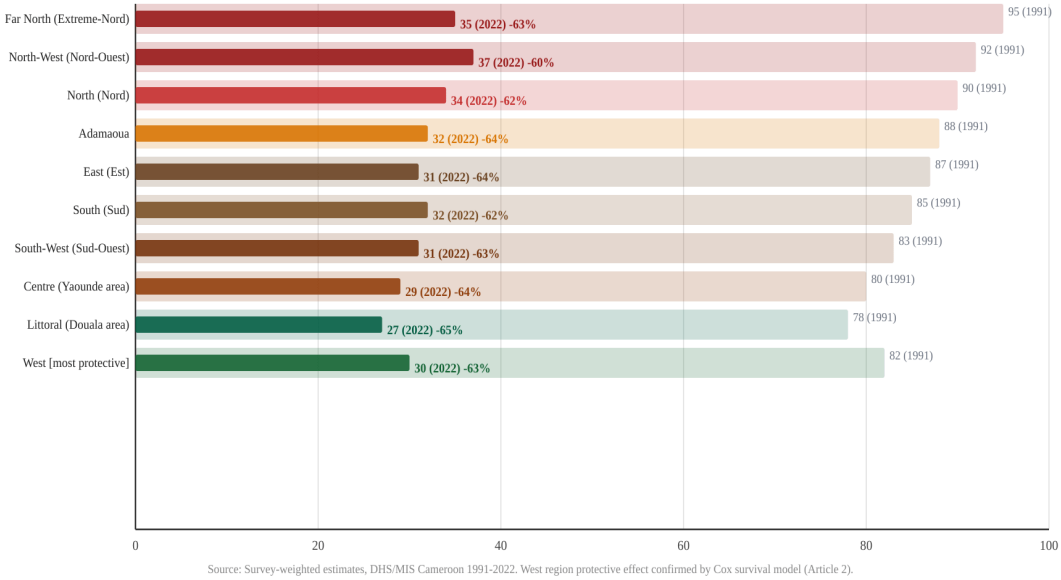


Figure 6. Regional U5MR: 1991 vs. 2022 Comparison — All Administrative Regions

Pale bars: 1991 U5MR. Dark bars: 2022 U5MR. Percentage: relative reduction. ✓West = most protective region, confirmed by Cox survival analysis (HR=0.675, p=0.001, Article 2).

Source: *survey-weighted estimates, DHS/MIS Cameroon.*

Discussion

Progress That Is Real but Inequitably Distributed

The 62.4% reduction in U5MR between 1991 and 2022 is a genuine public health achievement, attributable to documented expansions in immunization coverage [4, 5], nationwide malaria control through insecticide-treated nets and artemisinin-based combination therapy [6], improved management of diarrheal disease, and, from 2007 onward, free healthcare policies for children under five [17]. However, this progress has been structured by the types of interventions deployed: community-level programs that reduced vaccine-preventable, malaria-related, and diarrheal deaths have succeeded, facility-based neonatal care has not expanded commensurately. The consequence is the neonatal squeeze documented in this study: a 62% decline in overall U5MR alongside an essentially unchanged NMR, shifting the epidemiological focus of child death entirely toward the first month of life.

The 2004 Reversal: A Multi-Method Confirmed Anomaly

The anomalous 2004 peak (102.0‰, 95% CI: 94.2–109.0) is corroborated by four independent analytical approaches across this thesis series: direct weighted estimation, Cox proportional hazards (HR = 1.341, $p < 0.001$), discrete-time hazard modelling (OR = 1.341, $p = 0.0006$), and Bayesian hierarchical modelling (temporal fixed effect +0.25, 95% CrI: 0.10–0.40). This quadruple triangulation effectively rules out sampling artifact [15]. The most plausible explanations involve the convergence of expanded geographic coverage in 2004 (newly sampled northern communities with higher baseline mortality [11]), the sequelae of structural adjustment that constrained health service utilization in the early 2000s [17], peak malaria burden before the ITN scale-up of 2005–2010 [6], and a documented meningococcal meningitis epidemic in northern Cameroon in 2003–2004 [7]. The 2004 reversal constitutes a policy warning: health system progress can be rapidly and substantially undone by the

convergence of epidemiological, economic, and systemic stressors.

The Neonatal Squeeze and Its Policy Architecture

Meeting the SDG 3.2 neonatal target (NMR < 12 per 1,000 by 2030) from Cameroon's current NMR of approximately 28 per 1,000, with neonatal deaths accounting for an estimated 87% of all remaining U5M, requires a 57% reduction in neonatal deaths in less than a decade. This cannot be achieved by scaling community health programs that were never designed to address birth asphyxia, prematurity, or neonatal sepsis. The evidence base is unambiguous: essential newborn care packages (immediate newborn assessment, thermoregulation, early initiation of breastfeeding, neonatal resuscitation, and antibiotic treatment of sepsis) reduce neonatal mortality when delivered at the facility level by trained personnel [8, 18]. Cameroon's national skilled birth attendance rate of 69% (2018), masking rates below 30% in the Far North [4], is the binding constraint. Extending universal skilled birth attendance to the northern regions, combined with essential newborn care training for all skilled birth attendants, represents the single highest-impact investment available for the next decade.

Regional Priority and the West Region's Lesson

The four northern priority zones (Far North, North, Adamaoua, North-West) exhibit a pattern of multiple concurrent disadvantages (structural, educational, geographic, and epidemiological) that make single-sector interventions insufficient. The companion Fairlie decomposition analysis (Article 3) attributes approximately 49% of the gap between priority and non-priority zones to structural factors (health system quality, infrastructure, context-specific barriers) that cannot be addressed through individual-level interventions alone. Multisectoral programming, combining girls' education, family planning, water and sanitation, nutrition, and simultaneous health system strengthening, is the evidence-based approach for these settings [4, 17].

The West region's consistently protective profile, established as statistically significant across five independent analytical methods across this thesis series, points to contextual mechanisms worth understanding and replicating: historically higher educational attainment among Bamiléké communities, strong mutual aid traditions that buffer health expenditure shocks, relatively higher skilled birth attendance, and more robust community health infrastructure [17]. Documenting these mechanisms qualitatively and designing implementation strategies to transfer them to the northern regions represents a priority research and policy agenda.

Study Strengths and Limitations

The principal strength of this study is its analytical scope: six nationally representative surveys spanning 31 years, analyzed under a consistently declared and rigorously documented complex survey design. The use of composite PSU and strata identifiers prevents a common form of methodological error that systematically underestimates confidence intervals in multi-wave DHS analyses [15]. The availability of GPS cluster data for five of six waves enables regional mapping adding a spatial dimension to the epidemiological analysis.

Several limitations require acknowledgment:

1. The MIS 2022 did not collect the age-at-death variable (b7), preventing NMR estimation for the most recent wave; 2022 NMR values are approximate.
2. Retrospective birth histories are subject to recall bias; this is minimized by DHS standardized interviewing but cannot be entirely eliminated [20].

3. Cause-of-death data are not collected in DHS surveys; attribution to specific diseases requires ecological inference.
4. Regional estimates presented in Table 3 are approximate point estimates without wave-specific confidence intervals; exact Bayesian-smoothed regional estimates with credibility intervals are presented in the companion spatial analysis (Article 3).
5. The 1998 GPS file was not released by the DHS Program, limiting spatial analysis to five of six waves.

Conclusion

Six nationally representative surveys spanning 31 years document a Cameroon that has achieved meaningful progress in child survival while generating the conditions for its next, more difficult challenge. The 62.4% reduction in U5MR is real, well-documented, and the product of identifiable health investments. The anomalous 2004 reversal exposes the fragility of this progress. The neonatal squeeze, with neonatal deaths now accounting for an estimated 87% of all remaining under-five deaths, signals that the strategy that drove post-neonatal mortality down will not suffice to reach the SDG 3.2 neonatal target.

Cameroon is close to the SDG 3.2 under-five mortality target of 25 per 1,000 live births. Reaching it and simultaneously addressing the neonatal target of 12 per 1,000, requires an urgent reorientation of child survival investment toward facility-based essential newborn care, universal skilled birth attendance, and equity-targeted programming in the four northern priority regions. The data, and the children they represent, make the direction unmistakably clear. What remains is the programmatic architecture and the political will to act upon it.

Conflict of Interest

The author declares no conflict of interest.

Ethical Approval

This study is a secondary analysis of publicly available, de-identified DHS survey data. Ethical approval was granted to the original surveys by the Institut National de la Statistique du Cameroun and ICF Institutional Review Board. Secondary analysis of de-identified data does not require additional ethical review per DHS Program policy [15]. Data were accessed via dhsprogram.com following free institutional registration.

Data Availability

All DHS/MIS data are freely available at dhsprogram.com. Analytical code is available from the corresponding author on request. Reproducibility requires R 4.6.0 with the survey package [16].

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author Contributions

ZEBAZE Paul Narcisse: Conceptualization, data curation, formal analysis, methodology, visualization, writing (original draft and review/editing).

Acknowledgements

The author thanks the DHS Program and INS Cameroun for making survey microdata publicly available. Analyses were conducted in R 4.6.0.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art023

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Factors Associated with Multiple Micronutrient Supplementation Achievement During National Scale-Up in Ethiopia: A Longitudinal Analysis of Routine Monitoring Data

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Cite this article as: Abnet Tesfaye Kebede. Factors associated with multiple micronutrient supplementation achievement during national scale-up in Ethiopia: A longitudinal analysis of routine monitoring data. Texila Int J Acad Res. 2026;13(4). https://doi.org/10.21522/TIJAR.2014.13.04.Art023

Received: 09.09.2026

Accepted: 08.10.2026

Published: 30.10.2026

Article Type: Original Research

Abstract *Maternal micronutrient deficiencies remain a major public health challenge in Ethiopia and contribute to adverse maternal and newborn outcomes. Ethiopia introduced Multiple Micronutrient Supplementation (MMS) through routine antenatal care services and progressively expanded implementation nationwide. However, evidence regarding factors associated with implementation performance during large-scale program expansion remains limited. This study examined implementation and health-system factors associated with MMS achievement during national scale-up in Ethiopia. A longitudinal secondary analysis was conducted using routine MMS monitoring data collected between January 2023 and August 2026. The unit of analysis was the woreda-month observation. MMS achievement, defined as the percentage of pregnant women newly supplemented with MMS relative to the reported monthly target, was the primary outcome. Mixed-effects regression models with random intercepts for woredas were used to assess associations between MMS achievement and implementation factors. The analytical dataset included 2,268 implementation observations from 75 woredas across 13 regions, of which 1,724 (76.0%) had available MMS achievement data. Mean MMS achievement was 100.2% (SD 56.3), while the median was 94.6% (IQR 70.5–120.4). In adjusted analyses, community dialogue was associated with a 17.99-percentage-point higher MMS achievement (95% CI: 3.11–32.86; p = 0.018), and commodity availability was associated with a 23.50-percentage-point higher MMS achievement (95% CI: 14.08–32.92; p < 0.001). Health-worker training, supportive supervision, implementation status, reporting period, and regional comparisons were not independently associated with achievement after adjustment. Substantial between-woreda variation remained (ICC = 0.358). Commodity availability and community engagement were the strongest factors associated with higher MMS achievement. Strengthening supply-chain reliability, community engagement, and routine monitoring systems may improve MMS implementation performance during national scale-up in Ethiopia.*

Keywords *Community Engagement, Ethiopia, Health Systems, Implementation Performance, Implementation Science, Maternal Nutrition, Multiple Micronutrient Supplementation, Routine Monitoring.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art023

Introduction

Maternal micronutrient deficiencies remain a major public health challenge globally and are associated with adverse maternal and neonatal outcomes, including maternal anemia, low birth weight, preterm birth, fetal growth restriction, stillbirth, and neonatal mortality [2-6, 14, 15]. Despite substantial progress in maternal and child health services, micronutrient deficiencies continue to contribute significantly to the burden of maternal and child morbidity and mortality in low- and middle-income countries, where inadequate dietary diversity and multiple nutritional deficiencies frequently coexist [2-6, 14, 15].

Maternal nutrition remains a priority public health issue in Ethiopia. Previous national surveys have consistently documented the persistence of maternal and child nutritional challenges as well as regional disparities in maternal healthcare utilization across Ethiopia [16, 17]. Findings from the 2024–25 Ethiopia Demographic and Health Survey (EDHS) indicate that maternal and child malnutrition continues to present substantial challenges. Approximately 40% of children under five years of age remain stunted, while inadequate dietary diversity among women remains common, reflecting persistent nutritional vulnerabilities that may negatively affect maternal and newborn health outcomes. Maternal mortality also remains an important concern, with the 2024–25 EDHS reporting a maternal mortality ratio of 141 deaths per 100,000 live births [22]. These findings underscore the continued need for effective maternal nutrition interventions throughout pregnancy and highlight the importance of strengthening nutrition-related services within the healthcare system.

The continued expansion of maternal healthcare services provides an important opportunity to strengthen maternal nutrition programs. The 2024–25 EDHS reported that approximately 64% of births were attended by skilled health personnel and that antenatal care utilization has improved substantially over recent years [22]. These improvements create favorable conditions for integrating evidence-based maternal nutrition interventions into routine antenatal care. However, the success of such interventions depends not only on their clinical effectiveness but also on the ability of health systems to implement them effectively under routine program conditions [18-21].

Iron-Folic Acid (IFA) supplementation has historically been the standard antenatal nutrition intervention used to prevent maternal anemia and neural tube defects. However, increasing evidence from randomized trials, systematic reviews, and meta-analyses demonstrates that Multiple Micronutrient Supplementation (MMS) provides broader maternal and neonatal benefits than IFA alone [2-6, 14, 15]. MMS, commonly delivered using the United Nations International Multiple Micronutrient Antenatal Preparation (UNIMMAP), provides a combination of 15 essential vitamins and minerals designed to address the multiple micronutrient deficiencies frequently experienced during pregnancy [13]. Research has demonstrated that MMS reduces the risk of low birth weight, small-for-gestational-age births, and preterm delivery while improving maternal micronutrient status [2–6, 14, 15]. Consequently, MMS is increasingly recognized as an effective maternal nutrition intervention in settings characterized by widespread micronutrient deficiencies.

Recognizing these benefits, Ethiopia initiated a phased transition from IFA supplementation to MMS through routine antenatal care services beginning in 2023. The program was introduced in pilot implementation woredas and subsequently expanded as part of a broader national scale-up effort. Scale-up activities included health-worker training, supportive supervision, social and behavior change interventions, community engagement, routine monitoring, and supply-chain strengthening activities [1,7–12]. As

implementation expanded across increasingly diverse geographic and health-system contexts, understanding implementation performance became critical for informing program improvement, resource allocation, and equitable national expansion.

Although the effectiveness of MMS is well established, less evidence exists regarding implementation performance during program scale-up, particularly in low- and middle-income countries. Implementation-science literature suggests that program outcomes are shaped by interactions among implementation strategies, organizational readiness, health-system functionality, monitoring systems, and contextual characteristics [18-21]. Factors such as health-worker training, supportive supervision, community engagement, commodity availability, leadership, and program monitoring may influence implementation performance. However, the extent to which these factors contribute to MMS achievement under routine implementation conditions remains insufficiently understood [18-21].

Implementation-science frameworks proposed by Peters et al., Proctor et al., and the PRISM framework emphasize that successful program implementation depends on both implementation strategies and health-system readiness [18-21]. These frameworks provide a useful lens for understanding variation in program achievement across settings, time periods, and health systems. Community engagement, workforce capacity, commodity availability, and routine monitoring systems have frequently been identified as important influences on implementation outcomes, yet evidence from large-scale maternal nutrition programs remains limited [18-21].

Despite Ethiopia's ongoing transition from IFA supplementation to MMS, no national longitudinal study has comprehensively examined implementation and health-system factors associated with MMS achievement using routine program-monitoring data. Understanding these factors is important for strengthening program effectiveness, informing implementation-support strategies, identifying operational bottlenecks, and ensuring equitable expansion of MMS services across implementation settings. Therefore, this study aimed to identify implementation and health-system factors associated with MMS achievement during national MMS scale-up in Ethiopia using routine program-monitoring data.

Objective

To identify implementation and health-system factors associated with MMS achievement during national scale-up in Ethiopia.

Methods

Study Design and Data Source

This study used routinely reported program implementation data to assess MMS implementation performance and factors associated with MMS achievement in Ethiopia. The analytical dataset comprised monthly implementation observations reported by woredas participating in MMS implementation between 2023 and 2026. Each observation represented a woreda-level reporting record for a given reporting period.

The dataset included information on region, woreda, implementation status, the monthly number of pregnant women targeted for MMS, the number newly supplemented with MMS during the month, cumulative MMS supplementation, community dialogue activities, health-worker training, supportive supervision, and commodity availability.

Duplicate records were removed during data preparation. The final analytical dataset contained 2,268 implementation observations from 75 woredas across 13 regions.

Outcome Measure

The primary outcome was monthly MMS achievement (%), calculated as the number of

pregnant women newly supplemented with MMS during the reporting month divided by the reported monthly target for MMS, multiplied by 100:

$$\text{MMS achievement (\%)} = \frac{\text{Number of pregnant women newly supplemented with MMS during the reporting period}}{\text{Reported monthly MMS targets}} \times 100$$

Achievement values greater than 100% were retained because the reported number of women supplemented could exceed the reported monthly target. Such values may occur in routine program monitoring when supplementation during a reporting period exceeds the reported target. No observations were capped, truncated, or excluded from the primary analysis on the basis of achievement values.

Explanatory Variables

Four program implementation factors were examined as the primary explanatory variables: health-worker training, supportive supervision, community dialogue, and commodity availability.

Health-worker training was classified as Yes when the reported number of health workers trained on MMS during the relevant reporting period was greater than zero and No when the reported number was zero. Missing values remained missing.

Supportive supervision was similarly classified as Yes when at least one supportive supervision activity was reported and No when none was reported. Missing values were retained as missing.

Community dialogue was classified as Yes when the reported number of community dialogues or pregnant-women conferences conducted so far was greater than zero and No when the reported value was zero. Because this variable represented activities conducted cumulatively up to the reporting period, the binary indicator was used for the primary analysis rather than interpreting the reported cumulative count as a monthly exposure.

Commodity availability was classified as Yes when the woreda reported having sufficient MMS supplies to cover the needs of the coming three months and No when the response was explicitly reported as no. Responses recorded as "0" could not be reliably interpreted as either yes or no and were therefore treated as missing rather than recoded as inadequate availability.

Additional covariates included implementation status (existing versus expansion), year, and region. Existing implementation, 2023, and Addis Ababa were used as the reference categories, respectively.

Data Management and Missing Data

Data cleaning and analysis were conducted in R using RStudio. Duplicate observations were identified and removed before analysis. Variable formats and categorical response values were standardized during data preparation.

Missing values were not imputed for the primary analyses. Descriptive and bivariable analyses used all observations with available values for the outcome and variables included in each analysis.

For the multivariable analysis, a complete-case approach was used. Observations were included only when MMS achievement, all four primary implementation factors, implementation status, year, region, and woreda were simultaneously available. This resulted in 1,246 complete observations from 58 woredas, representing 54.9% of the 2,268 implementation observations. The extent of missing information was considered when interpreting the adjusted results.

Statistical Analysis

Descriptive statistics were used to summarize implementation observations and MMS achievement. Because MMS achievement was non-normally distributed and showed substantial variability, both mean with standard deviation and median with interquartile range were reported.

For comparisons of MMS achievement between the two categories of each implementation factor, the Wilcoxon rank-sum test was used because the outcome distribution was skewed and included extreme values. Results were summarized using the sample size, mean ± standard deviation, median and interquartile range, together with the corresponding Wilcoxon test *p*-value.

Bivariable associations between MMS achievement and each explanatory variable were examined using linear regression models. For binary variables, regression coefficients (β) represent the estimated difference in MMS achievement percentage points between the specified category and the reference category. For multi-category variables such as year and region, the overall significance of the variable was assessed using the model's overall test, and no single β coefficient was reported for the variable as a whole.

Multivariable Mixed-Effects Analysis

Because implementation observations were repeatedly reported from the same woredas over time, observations were not assumed to be statistically independent. A linear mixed-effects regression model with a random intercept for woreda was therefore fitted to account for clustering of observations within woredas.

The primary multivariable model included health-worker training, supportive supervision, community dialogue, commodity availability, implementation status, year, and region as fixed effects, with a random intercept for woreda:

$$Y_{ij} = \beta_0 + \beta_1\, Training\ ij + \beta_2\, Supervision\ ij + \beta_3\, Community\ Dialogue\ ij + \beta_4\, Commodity\ Availability\ ij + \beta_5\, Implementation\ Status\ ij + \beta_6\, Year\ ij + \beta_7\, Region\ ij + u_j + \varepsilon_{ij}$$

where:

- Y_{ij} = MMS achievement (%) for observation *i* in woreda *j*;
- β_0 = model intercept;
- $\beta_1 - \beta_7$ = fixed-effect coefficients;
- u_j = woreda-level random intercept;
- ε_{ij} = residual error term.

The model was fitted using maximum likelihood estimation. Adjusted regression coefficients, 95% confidence intervals, and *p*-values were reported. The intraclass correlation coefficient (ICC) was calculated to quantify the proportion of residual variation attributable to differences between woredas.

Overall model improvement was assessed by comparing the full mixed-effects model with a random-intercept-only model using a likelihood-ratio test.

Assessment of Multicollinearity

Potential multicollinearity among explanatory variables was evaluated using variance inflation factors (VIFs). No evidence of problematic multicollinearity was observed (all VIF values < 5).

Assessment of Model Assumptions and Sensitivity Analysis

The distribution of MMS achievement and model residuals was examined because the outcome demonstrated substantial right-skewness and included values considerably greater than 100%. Multicollinearity among explanatory variables was assessed using variance inflation factors.

Extreme achievement values were retained in the primary analysis because they represented observed program -monitoring data and could not be assumed to be erroneous solely because they exceeded 100%. However, to assess whether extreme observations materially influenced the findings, a prespecified sensitivity analysis was conducted by excluding observations with MMS achievement >300%.

The sensitivity analysis used the same complete-case mixed-effects modelling approach and covariates as the primary model. Estimates from the sensitivity model were compared with the primary model to assess

whether the direction and substantive conclusions of the associations were robust.

Statistical significance was assessed using a two-sided *p*-value threshold of <0.05. Given the observational nature of the routine monitoring data, associations were interpreted as statistical associations rather than causal effects.

Results

Characteristics of Implementation Observations

The final analytical dataset comprised 2,268 implementation observations from 75 woredas across 13 regions, covering the period from 2023 to 2026. Of these observations, 1,533 (67.6%) were from woredas classified as having existing MMS implementation, while 735 (32.4%) were from expansion woredas. The dataset contained 13 distinct reporting-month labels across the study period. These characteristics are summarized in Table 1.

Table 1. Characteristics of MMS Implementation Observations

Characteristic	Value
Implementation observations	2,268
Regions	13
Woredas	75
Existing implementation	1,533 (67.6%)
Expansion implementation	735 (32.4%)
Years covered	2023–2026
Distinct reporting-month labels	13

Distribution of Implementation Factors

The frequency distribution of the primary implementation factors is presented in Table 2.

Table 2. Distribution of Primary Implementation Factors

Variable	Category	n (%)
Health-worker training	Yes	311 (22.6)
Health-worker training	No	1,063 (77.4)
Supportive supervision	Yes	918 (67.9)
Supportive supervision	No	433 (32.1)
Community dialogue	Yes	1,370 (94.5)
Community dialogue	No	79 (5.5)
Commodity availability	Yes	1,176 (86.2)
Commodity availability	No	189 (13.8)

MMS Achievement and Implementation Factors

Overall, MMS achievement was available for 1,724 of the 2,268 observations. Among observations with available achievement data, the mean MMS achievement was 100.2% (SD 56.3), while the median was 94.6% (IQR 70.5–120.4). Achievement ranged from

0% to approximately 729%. Values exceeding 100% were retained because the number of pregnant women supplemented during a reporting month could exceed the reported monthly target.

MMS achievement differed significantly according to training status, supportive supervision, and commodity availability in the unadjusted group comparisons. Median achievement was lower among observations reporting health-worker training (89.3%) than among those reporting no training (98.0%; p = 0.002). In contrast, achievement was higher among observations with supportive supervision (97.5%) than those without supervision (93.1%; p = 0.010).

Community dialogue showed a higher median achievement among observations with dialogue activities (95.9%) compared with those without (86.1%), although the difference did not reach conventional statistical significance (p=0.063). Similarly, median achievement was higher where sufficient MMS commodities were reported to be available for the coming three months (96.2%) than where commodities were unavailable (90.6%; p = 0.022). The complete descriptive comparisons are presented in Table 3.

Table 3. MMS Achievement by Implementation Factors

Factor	Category	n	Mean ± SD (%)	Median (IQR) (%)	p-value
Training	No	1,063	103.9 ± 59.2	98.0 (73.0–123.4)	0.002
	Yes	311	96.7 ± 56.7	89.3 (72.3–106.5)	
Supportive supervision	No	433	99.9 ± 64.0	93.1 (66.4–122.5)	0.010
	Yes	918	104.8 ± 55.4	97.5 (77.9–121.4)	
Community dialogue	No	79	87.7 ± 59.2	86.1 (41.3–133.5)	0.063
	Yes	1,370	102.5 ± 57.9	95.9 (73.7–119.2)	
Commodity availability	No	189	96.1 ± 55.9	90.6 (63.6–111.7)	0.022
	Yes	1,176	104.2 ± 58.5	96.2 (74.7–121.6)	

Note: *p-values are from Wilcoxon rank-sum tests. Percentages above 100% were retained in the primary analysis.*

Percentages are based on observations with available values for the corresponding variable. Community dialogue activities were widely reported across implementation observations, whereas health worker training occurred less frequently. Supportive supervision and commodity availability were reported in the majority of eligible implementation observations.

The distribution of MMS achievement across the four implementation factors is further illustrated in Figure 1. The figure demonstrates substantial variability within all groups and highlights the presence of high achievement values, particularly among observations reporting commodity availability and community dialogue.

https://doi.org/10.21522/TIJAR.2014.13.04.Art023

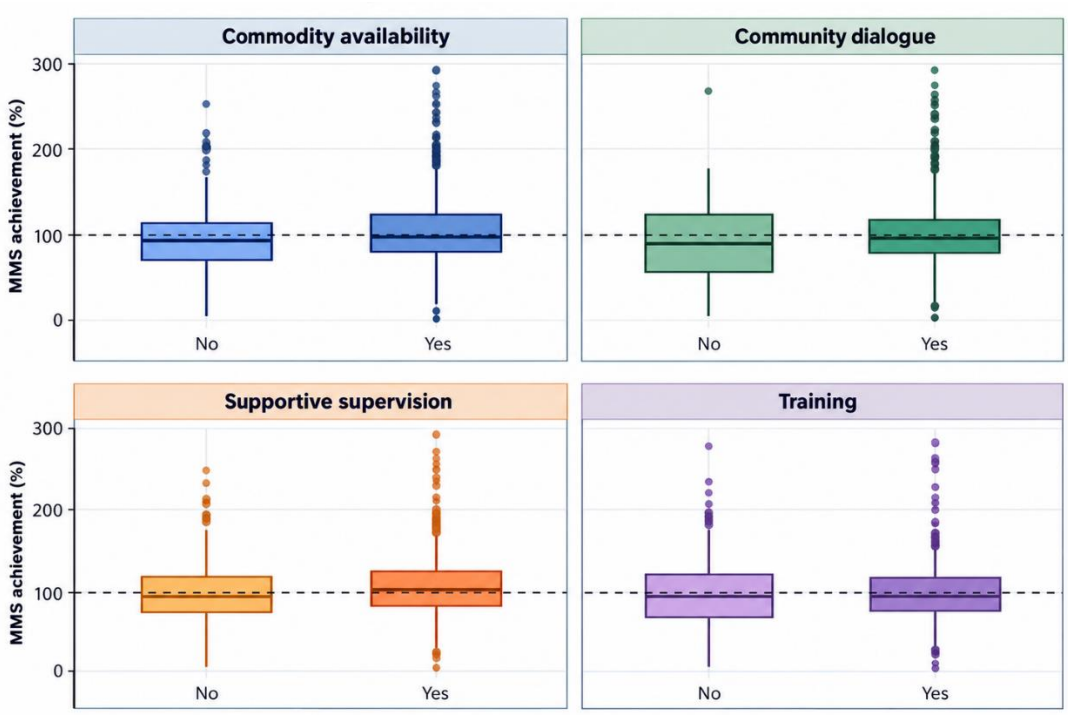


Figure 1. Distribution of MMS Achievement According to Implementation Factors, Ethiopia, 2023–2026

Note: *The figure illustrates the distribution of MMS achievement across categories of health-worker training, supportive supervision, community dialogue, and commodity availability. Percentages greater than 100% were retained in the primary analysis.*

Bivariable Relationships with MMS Achievement

Bivariable linear regression was subsequently used to quantify the unadjusted relationship between MMS achievement and each explanatory variable. Community dialogue was positively associated with MMS achievement, with observations reporting community dialogue having an estimated 14.8-percentage-point higher achievement than observations without reported dialogue ($\beta = 14.81$, $p = 0.027$).

Training status was associated with a 7.20-percentage-point lower achievement among observations reporting training compared with those reporting no training, although this association was not statistically significant ($\beta = -7.20$, $p = 0.057$). Supportive supervision was associated with a 4.88-percentage-point higher achievement, but this was also not statistically significant ($p = 0.152$).

Commodity availability was associated with an estimated 8.11-percentage-point higher achievement among observations reporting sufficient commodities, although the association was not statistically significant at the 5% level ($p = 0.076$). Implementation status was not associated with achievement ($\beta = -2.31$, $p = 0.438$). Year was not significantly associated with MMS achievement overall ($p = 0.117$), whereas region showed strong overall evidence of geographic variation ($p < 0.001$). The bivariable findings are summarized in Table 4.

Table 4. Bivariable Relationships with MMS Achievement

Variable	β	p-value
Training (Yes vs No)	−7.20	0.057
Supportive supervision (Yes vs No)	4.88	0.152

Community dialogue (Yes vs No)	14.81	0.027
Commodity availability (Yes vs No)	8.11	0.076
Implementation status (Expansion vs Existing)	−2.31	0.438
Year	—	0.117
Region	—	<0.001

Note: *β represents the unadjusted mean difference for binary variables. For year and region, the p-value represents the overall test from the corresponding bivariable regression model.*

Multivariable Mixed-Effects Analysis

Because observations were repeatedly reported within woredas, a linear mixed-effects model incorporating a woreda-level random intercept was fitted to account for clustering. The multivariable analysis was based on 1,246 complete observations from 58 woredas, representing 54.9% of the full analytical dataset.

After simultaneous adjustment for training, supportive supervision, community dialogue, commodity availability, implementation status, year, and region, community dialogue and commodity availability remained significantly associated with MMS achievement.

Observations reporting community dialogue had an estimated 18.0-percentage-point higher MMS achievement compared with observations without reported dialogue (β = 17.99, 95% CI: 3.11–32.86; p = 0.018). Similarly, observations reporting sufficient commodity availability had an estimated 23.5-percentage-point higher MMS achievement compared with those reporting insufficient commodity availability (β = 23.50, 95% CI: 14.08–32.92; p < 0.001).

Training status, supportive supervision, implementation status, year, and individual regional comparisons were not statistically significant after adjustment. The adjusted associations are presented in Table 5.

Table 5. Multivariable Mixed-Effects Model of MMS Achievement

Variable	**β**	**95% CI**	**p-value**
Intercept	57.2	8.89 to 106	0.021
Training (Yes vs No)	−1.78	−10.45 to 6.89	0.687
Supportive supervision (Yes vs No)	−1.67	−8.69 to 5.34	0.640
Community dialogue (Yes vs No)	18.0	3.11 to 32.9	0.018
Commodity availability (Yes vs No)	23.5	14.08 to 32.9	<0.001
Implementation status (Expansion vs Existing)	−2.94	−29.71 to 23.8	0.827
Year 2024 vs 2023	0.91	−8.8 to 10.6	0.854
Year 2025 vs 2023	−2.04	−11.43 to 7.34	0.669
Year 2026 vs 2023	4.34	−6.49 to 15.2	0.431
Afar vs Addis Ababa	0.61	−74.77 to 76.0	0.987
Amhara vs Addis Ababa	4.11	−49.96 to 58.2	0.880
BG vs Addis Ababa	−11.3	−105.0 to 82.3	0.810
Gambela vs Addis Ababa	2.15	−83.3 to 87.6	0.960
Oromia vs Addis Ababa	14.5	−34.63 to 63.7	0.557

SER vs Addis Ababa	19.2	−74.58 to 113	0.684
Sidama vs Addis Ababa	−3.93	−72.57 to 64.7	0.909
SNNP vs Addis Ababa	11.4	−42.48 to 65.3	0.674
Somali vs Addis Ababa	−12.4	−69.19 to 44.4	0.664
Tigray vs Addis Ababa	34.5	−22.86 to 91.9	0.233

Note: *The model included a random intercept for woreda. Reference categories were No training, No supportive supervision, No community dialogue, No commodity availability, Existing implementation, 2023, and Addis Ababa.*

Temporal Variation in MMS Achievement

MMS achievement demonstrated variation over time across the observed reporting periods. Monthly mean achievement ranged from 84.0% to 127.0%, with a median monthly mean of 102.6%. Overall, the monthly estimates fluctuated around the 100% achievement benchmark, with no statistically significant independent effect of year in the multivariable model.

The temporal pattern of mean MMS achievement across the observed reporting periods from 2023 through 2026 is presented in Figure 2.

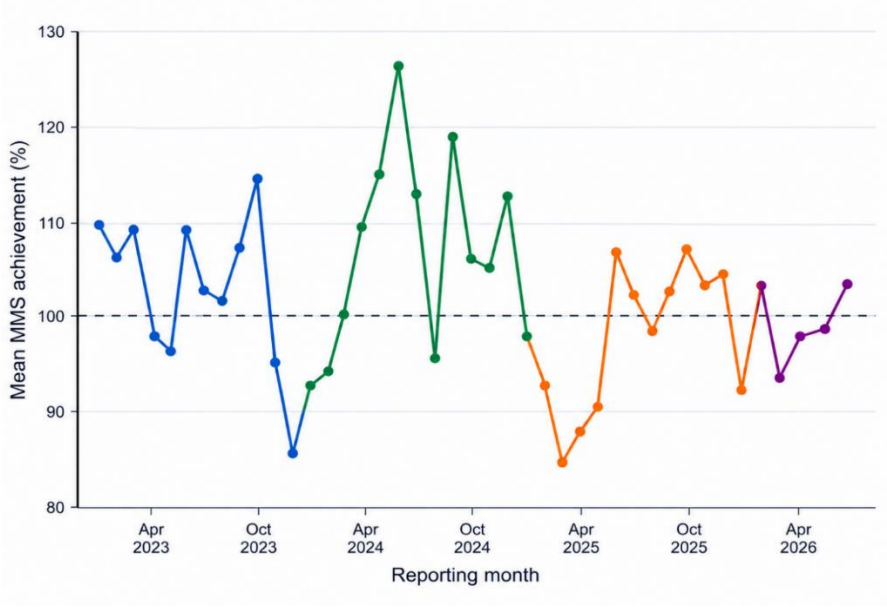


Figure 2. Monthly Mean MMS Achievement Across Reporting Periods, Ethiopia, 2023-2026

Note: *Only reporting periods with available MMS achievement observations are shown. Months without observations were not interpreted as zero achievement.*

Geographic Variation in MMS Achievement

There was substantial geographic variation in MMS achievement. Median achievement was highest in Oromia and Dire Dawa (102.0% each), followed by SNNP (100.0%) and Addis Ababa (98.2%). The lowest median achievement was observed in Somali (64.1%), followed by Tigray (77.3%), Afar (79.4%), Harari (81.1%), and BG (82.1%).

The regional distributions are shown in Figure 3. Although the bivariable analysis indicated strong overall regional variation, individual regional coefficients were not statistically significant after adjustment for the implementation factors, year, and woreda-level clustering.

https://doi.org/10.21522/TIJAR.2014.13.04.Art023

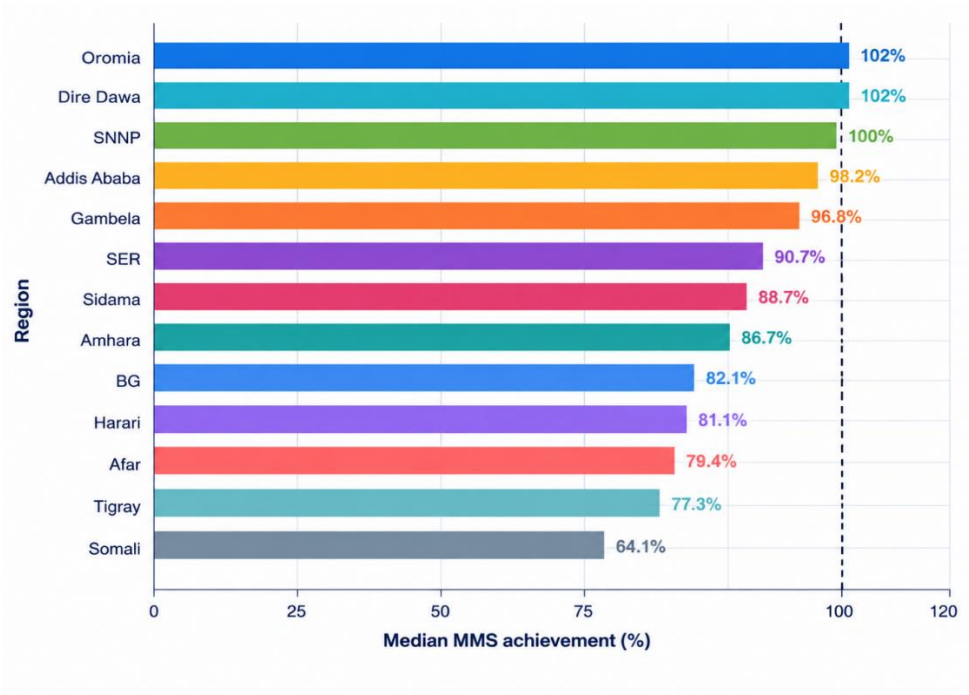


Figure 3. Regional Variation in Median MMS Achievement, Ethiopia, 2023-2026

Model Fit, Clustering, and Sensitivity Analysis

The random-intercept model indicated substantial clustering of MMS achievement within woredas. The adjusted intraclass correlation coefficient (ICC) was 0.358, indicating that approximately 35.8% of the residual variation in MMS achievement was attributable to differences between woredas after accounting for the fixed effects in the model.

The full mixed-effects model provided a significantly better fit than the woreda-only random-intercept model (likelihood-ratio $\chi^2 = 37.6$, df = 18, p = 0.0044). The model had an AIC of 13,359 and BIC of 13,466. These model-fit statistics are summarized in Table 6.

Table 6. Overall Model Fit and Clustering Statistics

Statistic	Value
Observations	1,246
Woredas	58
Random-intercept variance	1,274
Residual variance	2,288
Adjusted ICC	0.358
AIC	13,359
BIC	13,466
Likelihood-ratio χ^2	37.6
Degrees of freedom	18
Overall model p-value	0.0044

Because the distribution of MMS achievement was strongly right skewed and included extreme values, a sensitivity analysis was conducted excluding observations with achievement >300%. This removed 12 of the 1,246 complete-case observations (1.0%), leaving 1,234 observations.

The principal findings were unchanged. Community dialogue remained positively associated with achievement ($\beta = 12.38$, $p = 0.027$), while commodity availability remained strongly associated with higher achievement ($\beta = 12.50$, $p < 0.001$). Training ($\beta = -0.49$, $p = 0.880$), supportive supervision ($\beta = -0.32$, $p = 0.904$), and implementation status ($\beta = -3.90$, $p = 0.705$) remained non-significant. The adjusted ICC was 0.380, compared with 0.358 in the primary model.

Overall, the sensitivity analysis supported the robustness of the two principal adjusted associations despite the presence of extreme achievement values.

Model Diagnostics

No evidence of problematic multicollinearity was identified among explanatory variables. Variance inflation factors for all predictors were below the accepted threshold of 5, indicating that the regression coefficients were not materially affected by collinearity.

Discussion

Principal Findings

This study examined routine implementation data generated during the national scale-up of multiple micronutrient supplementation (MMS) among pregnant women in Ethiopia. The analysis included 2,268 implementation observations from 75 woredas across 13 regions and examined MMS achievement in relation to key implementation and health-system factors.

Overall, MMS achievement showed substantial variability, with a median achievement of 94.6% and a mean of 100.2%. Achievement values above 100% were observed in a proportion of implementation observations, indicating that the number of women supplemented during a reporting period sometimes exceeded the reported monthly target. Rather than treating these values as erroneous a priori, they were retained in the primary analysis because they may reflect changes in target estimates, intensified implementation activities, or supplementation of women not captured in the monthly target denominator.

The most important finding was that commodity availability and community dialogue were the only implementation factors independently associated with higher MMS achievement after adjustment.

In the multivariable mixed-effects model, availability of sufficient MMS commodities was associated with an approximately 23.5-percentage-point higher achievement, while reporting community dialogue was associated with an approximately 18.0-percentage-point higher achievement. These associations remained statistically significant after adjustment for training, supportive supervision, implementation status, year, region, and clustering at woreda level.

These findings suggest that sustained implementation performance depends not only on introducing MMS into routine services but also on ensuring that the essential inputs and demand-side mechanisms required for implementation are functioning. In particular, reliable commodity availability represents a fundamental prerequisite for service continuity, while community dialogue may strengthen awareness, acceptance, demand, and utilization of MMS services.

The analysis also demonstrated substantial variation between woredas. The adjusted ICC of 0.358 indicates that a meaningful proportion of unexplained variation in MMS achievement occurred at the woreda level. This suggests that local health-system capacity, management practices, implementation context, and other woreda-level characteristics may influence

implementation performance beyond the individual implementation factors measured in the routine monitoring system.

Implementation Strategies

Training

Health-worker training was associated with MMS achievement in the descriptive and bivariable analyses, but the direction of association was not consistent with the expectation that training alone would improve performance. In the bivariable analysis, observations reporting training had lower mean and median achievement than those without reported training, although the adjusted association was no longer statistically significant.

This finding should not be interpreted as evidence that training is ineffective. Rather, training status in the routine dataset was defined by whether training was reported during the observation period and does not capture important dimensions such as training quality, timing, competency, refresher training, staff turnover, post-training mentoring, or whether trained personnel were actually delivering MMS services. In addition, training may have been prioritized in lower-performing or newly expanding areas, creating a plausible reverse-causality or targeting effect.

For national scale-up, training should therefore be viewed as one component of a broader implementation package rather than as a stand-alone intervention. Training should be linked to competency assessment, supportive supervision, practical mentoring, job aids, and mechanisms to orient newly deployed health workers.

Supportive Supervision

Supportive supervision was associated with slightly higher MMS achievement in the descriptive comparison and bivariable analysis, but the association was not statistically significant after adjustment. This suggests that the presence of supervision alone may not be sufficient to explain differences in MMS implementation performance.

The routine monitoring indicator captures whether supportive supervision occurred and the number of supervision activities but does not assess the quality or content of supervision. Effective supportive supervision may depend on whether supervisors identify implementation bottlenecks, provide immediate technical assistance, review data quality, address commodity problems, and follow up on agreed corrective actions.

Consequently, future implementation monitoring should move beyond counting supervision visits and capture selected measures of supervision quality and follow-up. A supervision system that is linked to performance review and problem-solving may have greater value than supervision measured only by frequency.

Community Engagement

Community dialogue emerged as one of the strongest predictors of MMS achievement. Observations reporting community dialogue had substantially higher achievement than those without reported dialogue, and this association remained significant after adjustment.

This finding highlights the importance of demand creation and community engagement as part of MMS implementation. Community dialogue may improve understanding of the benefits of MMS, address concerns or misconceptions, encourage antenatal care attendance, and increase acceptance and uptake among pregnant women.

The finding is particularly relevant because the community dialogue indicator was cumulative, representing activities conducted "so far." Therefore, the association should be interpreted as evidence that implementation environments with established community engagement were associated with better MMS achievement, rather than as evidence that one additional dialogue session directly increased achievement.

Future programming should strengthen structured community engagement through pregnant-women forums, community leaders, health extension workers, women's groups, and other locally appropriate platforms. Importantly, community engagement should be linked to service availability so that increased demand can be translated into actual supplementation.

Health-System Readiness

Commodity Availability

Commodity availability emerged as the strongest factor associated with higher MMS achievement. Woredas reporting sufficient MMS supplies for the subsequent three months achieved approximately 23.5 percentage points higher MMS achievement than woredas reporting inadequate supplies, after adjustment for implementation factors, reporting period, region, and woreda-level clustering. This finding underscores the importance of supply-chain readiness in sustaining implementation performance. The association remained significant after adjustment, suggesting that commodity availability is not merely a characteristic of better-performing implementation areas but a critical health-system condition supporting effective MMS delivery. Similar findings have been reported in implementation research, where uninterrupted availability of commodities has been identified as a prerequisite for achieving high service coverage and maintaining program continuity [2, 18, 19].

For Ethiopia's national MMS scale-up, strengthening forecasting, procurement, distribution, stock monitoring, and redistribution mechanisms should remain a priority. Ensuring adequate buffer stocks may be particularly important in areas experiencing logistical constraints, emergencies, or disruptions to routine supply systems [2, 18, 19].

Reporting Systems

The study also highlights the importance of routine monitoring and reporting systems for implementation performance. Although the routine monitoring database enabled assessment of MMS implementation across multiple years and regions, substantial missing information was observed for several implementation indicators, and complete-case analysis was possible for only 1,246 of the 2,268 implementation observations.

Incomplete reporting may limit the ability of routine monitoring systems to accurately reflect implementation performance and may reduce their usefulness for program decision-making. Strengthening reporting systems through standardized indicator definitions, routine data-quality checks, timely feedback mechanisms, and integration with existing health information systems could improve both data completeness and program monitoring capacity [20, 21].

Together, these findings suggest that health-system readiness extends beyond commodity availability alone and depends on functional monitoring systems capable of generating reliable information for implementation planning, adaptive management, and performance improvement [20, 21].

Program Implications

The findings have practical implications for the major institutions supporting maternal nutrition and MMS scale-up in Ethiopia.

Ministry of Health: The Ministry should strengthen MMS institutionalization within routine maternal and antenatal nutrition services, with particular attention to commodity security, standardized implementation guidance, routine performance monitoring, and integration of MMS indicators into national monitoring systems. Regional and woreda health offices should use routine data to identify low-performing areas and implement targeted corrective actions.

Ethiopian Public Health Institute (EPHI): EPHI can support national learning through

analysis of routine MMS monitoring data, development and strengthening of data-quality systems, operational research, and evaluation of implementation strategies. EPHI can also contribute to establishing standardized approaches for interpreting routine MMS performance indicators and documenting lessons from different implementation contexts.

UNICEF: UNICEF can support government-led scale-up through technical assistance on maternal nutrition, health-system strengthening, supply-chain readiness, monitoring and evaluation, capacity development, and evidence generation. The findings particularly support continued investment in systems that ensure commodity availability and strengthen community engagement rather than focusing exclusively on training activities.

Nutrition International: Nutrition International can contribute technical and implementation expertise in maternal nutrition and MMS programming, including support for evidence-based implementation approaches, capacity strengthening, demand generation, and learning from implementation across different settings. Collaboration with government systems will be important to ensure that successful approaches can be institutionalized and sustained.

Children's Investment Fund Foundation (CIFF): CIFF and other development partners can support scale-up through strategic investment in interventions that strengthen the enabling systems for MMS implementation, including supply-chain reliability, data and learning systems, implementation research, and approaches that improve equitable access and sustained program performance. Investments should increasingly emphasize system capacity and sustainability alongside short-term coverage gains.

Across all partners, the findings support a shift from viewing MMS scale-up primarily as a commodity-delivery intervention toward a systems-oriented implementation approach in which supply availability, community engagement, workforce capacity, supervision, and routine data systems are addressed together.

Continued implementation performance is likely to depend on reliable commodity availability, continued community engagement, and strong monitoring systems.

Strengths

This study has several important strengths. First, it used national routine monitoring data, providing a real-world assessment of MMS implementation under routine program conditions rather than under controlled research conditions. This increases the practical relevance of the findings for national program management.

Second, the dataset included observations collected across multiple years, allowing assessment of longitudinal implementation performance and temporal patterns during the national MMS scale-up.

Third, the study had broad geographic coverage, including 75 woredas across 13 regions. This allowed assessment of geographic variation and increased the relevance of the findings across diverse implementation contexts.

Fourth, the analysis incorporated an implementation science-oriented framework, examining implementation strategies, health-system readiness, community engagement, and contextual characteristics rather than focusing solely on coverage outcomes.

Finally, the use of a woreda-level random intercept accounted for the repeated nature of observations within woredas and demonstrated substantial clustering in implementation performance. Sensitivity analysis excluding observations with achievement above 300% produced similar substantive conclusions, supporting the robustness of the principal findings.

Limitations

Several limitations should be considered when interpreting the findings. First, the study relied on routine program data, which may be affected by differences in data completeness, accuracy, indicator interpretation, and reporting practices across regions and woredas. The observed achievement values above 100% and substantial missingness in several indicators illustrate some of these challenges.

Several implementation constructs were measured using binary or simplified routine indicators that may not adequately capture implementation dose, quality, fidelity, timing, or intensity. Consequently, the observed associations may underestimate or obscure relationships between higher-quality implementation strategies and MMS performance.

Second, missing observations were substantial. The primary multivariable analysis used a complete-case approach, resulting in 1,246 observations from 58 woredas compared with 2,268 observations in the overall analytical dataset. If observations with missing information differed systematically from complete observations, selection bias may have occurred.

Third, observational design prevents causal inference. Associations between commodity availability, community dialogue, and MMS achievement should not be interpreted as proof that these factors directly caused higher achievement. Unmeasured contextual and organizational factors may have contributed to the observed relationships.

Fourth, the study may be affected by reporting bias. Implementation activities such as training, supervision, and community dialogue were based on routine reporting and may not always reflect the quality, intensity, or actual implementation of the reported activities. Similarly, commodity availability was based on reported status rather than independent verification of stock levels.

Finally, some implementation variables were measured using relatively broad indicators. For example, training status did not capture training quality or competency, while the community dialogue measure was cumulative rather than period specific. These measurement limitations may have attenuated or obscured some associations.

Despite these limitations, the consistency of the principal findings in the sensitivity analysis and the use of a mixed-effects approach to account for woreda-level clustering strengthen confidence that commodity availability and community engagement are important correlates of MMS implementation performance.

Conclusion

MMS implementation performance during national scale-up was most strongly associated with commodity availability and community engagement activities. Strengthening these implementation and health-system factors may improve the effectiveness of MMS implementation in Ethiopia.

The findings suggest that successful MMS implementation requires more than expanding service availability. Reliable commodity supply, meaningful community engagement, functional monitoring systems, and locally responsive health-system management are central to maintaining implementation performance. Strengthening these components within routine maternal nutrition and antenatal care systems may improve the consistency, equity, and sustainability of MMS delivery.

These findings provide practical evidence for the Ministry of Health, EPHI, UNICEF, Nutrition International, CIFF, and other partners to prioritize health-system readiness, supply-chain reliability, community engagement, data-quality improvement, and institutionalization of MMS within routine services as Ethiopia continues national MMS scale-up.

Conflict of Interest

The author declares no conflict of interest regarding the publication of this study.

Data Availability

The data used in this study were obtained from the national MMS routine monitoring system and are not publicly available. Access may be granted by the relevant program authorities subject to applicable data-sharing requirements.

Ethics Approval

This study utilized secondary analysis of routinely collected, aggregated MMS program monitoring data and did not involve direct contact with human participants. The dataset contained no personal identifiers and was analyzed solely for research purposes.

Author Contributions

Abnet Tesfaye Kebede conceived the study, conducted the data analysis, interpreted the findings, and prepared the manuscript.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Acknowledgements

The author acknowledges the Ministry of Health, the Ethiopian Public Health Institute (EPHI), and partners supporting the national MMS program for facilitating access to routine monitoring data (UNICEF). Appreciation is also extended to academic supervisors and colleagues who provided technical guidance during the study.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research ISSN: 2520-3088

https://doi.org/10.21522/TIJAR.2014.13.04.Art024 Volume 13 Issue 4, 2026

Co-Infection of Lassa Fever-Malaria (LF) in Endemic Settings: Influence on LF Case Detection in Health Facilities in Ondo State, Nigeria

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Cite this article as: Saiki Adinoyi Musa, Abiodun Olaiya Paul, Stephen Fagbemi. Co-Infection of Lassa Fever-Malaria (LF) in Endemic Settings: Influence on LF Case Detection in Health Facilities in Ondo State, Nigeria. *Texila Int J Acad Res*. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art024**

Received: 01.08.2026

Accepted: 21.09.2026

Published: 30.10.2026

Article Type: Original Research

Abstract *In malaria-endemic settings, a positive malaria result may explain fever while Lassa fever (LF) remains clinically possible. This study assessed LF-malaria co-infection, probable missed LF suspicion, and diagnostic delays in selected health facilities in Ondo State, Nigeria. A convergent mixed-methods design combined retrospective review of 463 LF and malaria records from 2021 – 2023 across 10 purposively selected facilities in five high-burden LGAs with nine key-informant interviews. Co-infection required positive LF and malaria laboratory results. Quantitative data were analysed using descriptive statistics, chi-square tests and logistic regression; qualitative findings were analysed thematically and integrated through a joint display. All 463 records were purposefully selected as confirmed LF cases. Of these, 297 (64.1%) had positive LF and malaria results. Malaria was suspected in 440 (95.0%) records, and 324 (70.0%) had prior malaria treatment. Probable missed LF suspicion occurred in 103 (22.2%) records. Malaria positivity was associated with missed suspicion (adjusted odds ratio [aOR] 5.30, 95% CI 2.13–13.19; $p < 0.001$). Interviews highlighted symptom overlap, malaria-first reasoning, treatment failure, restricted RT-PCR access, specimen-transport barriers, notification gaps and uneven refresher training. Overall, 386 (83.4%) patients recovered and 53 (11.4%) died; the case-fatality proportion among confirmed LF records was 11.4%. In this selected sample, malaria appeared to mask LF rather than establish an independent cause of mortality. Malaria confirmation should not close the LF detection pathway. Parallel assessment, timely LF specimen collection, reliable transport, effective surveillance communication and practical diagnostic algorithms may support earlier detection.*

Keywords *Co-Infection, Lassa Fever, Malaria, Mixed-Methods, Suspicion-Index.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art024

Research in Context

Evidence Before this Study

Early LF is clinically non-specific and can resemble malaria and other acute febrile illnesses. Malaria-LF co-infection has been documented in Nigeria, but less is known about how malaria positivity affects the first clinical decision to suspect LF within routine care. Previous Nigerian and Ondo State studies have described LF burden, delayed presentation, clinical overlap and healthcare-worker knowledge gaps, but the pathway linking malaria diagnosis to missed LF suspicion has received less attention [1-5].

Added Value of this Study

This study links record-based evidence with accounts from state, LGA and facility-level actors involved in LF detection. The quantitative analysis identified a sizeable association between malaria positivity and probable missed LF suspicion. The interviews then showed how the association can arise in practice: malaria is considered first, a positive result can reduce further suspicion, and LF is often reconsidered only after symptoms persist, treatment fails or the patient returns. The study therefore treats missed detection as a pathway problem rather than as an isolated clinician error.

Implications of All the Available Evidence

In a LF- and malaria-endemic setting, a positive malaria result should not function as a rule-out test for LF. A practical response is a dual-pathway fever algorithm in which malaria testing continues, while LF assessment is triggered by clinical persistence, severity, epidemiological exposure, repeat attendance or other compatible features. Where the trigger is met, LF specimen collection should not wait for several failed malaria treatment courses.

Introduction

Lassa fever is an acute zoonotic viral haemorrhagic disease of public health importance in West Africa. Nigeria experiences recurrent outbreaks and remains one of the countries carrying the greatest reported burden. Ondo State has repeatedly been identified as a high-burden setting, with spatial clustering and recurrent transmission documented in several local government areas [6]. The continuing burden makes early case recognition important for treatment, infection prevention and control, surveillance and outbreak response.

The first clinical encounter with LF is often difficult. Fever, weakness, headache, vomiting, diarrhoea, myalgia and sore throat are common early manifestations. These features overlap with malaria and other acute febrile illnesses [7-10]. Bleeding, shock, facial oedema and organ dysfunction can increase clinical suspicion, but waiting for such features risks losing the period when early recognition is most useful. Delayed presentation and delayed recognition have been associated with poorer clinical trajectories among Nigerian LF patients [2, 4].

Malaria creates a particular diagnostic context. It is common, familiar and routinely testable at many points of care. LF requires a different chain of action: clinical suspicion, notification, safe specimen collection, transport and laboratory confirmation, often through a centralized molecular testing network. A malaria result can therefore be correct without being complete. A patient can have malaria, LF or both. Nigerian evidence has previously documented malaria parasitaemia among LF patients [5, 11, 12].

The clinical challenge is not simply symptom overlap. It also concerns how clinicians respond to uncertainty. Diagnostic reasoning literature describes premature closure as a situation in which an initially plausible explanation receives disproportionate weight before alternative explanations have been adequately considered [13]. In malaria-endemic settings, the high prior probability of malaria can make this tendency understandable. The public health problem arises when a positive malaria result ends the search even though the

patient remains clinically or epidemiologically compatible with LF.

The health-system context can reinforce this process. Donabedian's structure–process–outcome model provides a useful way of viewing the pathway. Laboratory availability, trained personnel, transport and reporting systems form part of the structure. Clinical assessment, testing, notification, sample collection and referral form the process. Missed suspicion, delayed confirmation, repeated treatment and adverse outcomes are possible consequences [14]. Evidence from Ondo State has already documented knowledge gaps and limitations in infection-prevention resources among healthcare workers [1, 15].

This study was designed to examine the interaction more directly. It focused on the occurrence of LF-malaria co-infection, the characteristics of patients and healthcare settings associated with poor detection, the dynamics of missed LF suspicion and healthcare workers' accounts of how cases move through the diagnostic pathway. The central proposition was not that malaria treatment is inappropriate. Rather, it was that malaria-focused clinical reasoning can become a masking mechanism when LF remains possible. The study, therefore, addressed four linked objectives: (i) determine the proportion of LF and malaria co-infection, and probable missed cases of LF in 5 endemic LGAs from 2021 to 2023 in Ondo State; (ii) establish the socio-demographic characteristics and care-seeking behaviour of suspected febrile illness cases associated with case detection of LF in endemic LGAs in Ondo State; (iii) understand the practices of health workers and facility structures or capacities associated with LF case detection among selected health facilities in Ondo State; and (iv) to explore health workers' perspectives on clinical decision-making or suspicion index, case/patient pathways, and clinical and health-system factors contributing to missed or delayed detection of LF in selected health facilities in Ondo State. The study hypothesized that malaria positivity and malaria-first treatment pathways would be associated with a greater probability of missed LF suspicion.

Materials and Methods

Study Design and Setting

A convergent mixed-methods design was used. The quantitative strand retrospectively linked LF surveillance records with outpatient and malaria records. The qualitative strand used key-informant interviews with public-health leaders, disease-surveillance and notification officers and frontline healthcare workers. Both strands examined the same broad phenomenon from different positions in the health system and were integrated during interpretation through a joint display [16, 17].

The study was conducted in Ondo State, south-western Nigeria. Five high-burden LGAs were represented: Owo, Ose, Akure South, Akure North and Akoko South-West. Ten facilities were included across tertiary, secondary, primary and private sectors. The purposive selection was intended to follow the diagnostic pathway across levels of care. It was not designed to produce a population-representative estimate for Ondo State.

Quantitative Population, Sampling and Data Sources

The state line list recorded 161, 375, and 439 confirmed Lassa fever (LF) cases in the selected LGAs in 2021, 2022, and 2023, respectively, totaling 975 cases. Of these, 463 records were verified at the selected facilities and included in the quantitative analytic dataset following purposive selection and linkage with outpatient, malaria, laboratory, and surveillance records. The remaining 512 line-listed cases were not represented in the verified analytic dataset because of the cases were recorded against other health facilities within the selected endemic LGA. Poor quality of data such as incomplete data entry and missing variables that prevented record triangulation were also

among the possible reasons for this discrepancy.

Therefore, the 463 records constituted the verified analytic sample rather than the complete line-listed population of confirmed LF cases. Data were abstracted on sociodemographic characteristics, clinical presentation, diagnostic procedures, malaria treatment, delays, and outcomes. Inconsistent labels and duplicate fields were cleaned during data processing. Two implausible age values were excluded from age-specific summaries but retained in other analyses.

Operational Definitions

Laboratory-confirmed LF was defined as a positive LF laboratory-result field. Primary co-infection required positive LF and positive malaria laboratory results in the same abstracted record. This direct laboratory definition was used because the dedicated co-infection field did not agree perfectly with the two laboratory fields. Probable co-infection without direct laboratory confirmation was not included in the primary estimate.

The study abstraction instrument operationalized LF case-definition fulfilment as fever of at least 38°C that failed to respond to appropriate antimalarial and antibiotic treatment within 48 – 72 hours, particularly during the peak season or in the presence of epidemiological risk, or compatible illness accompanied by recent rodent exposure or contact with a probable or confirmed case. This reflects the study instrument and the principles of national and international suspected-case definitions, recognizing that case guidance evolves [16].

Probable missed LF suspicion was defined as a record indicating that the patient met the study's operational LF case definition but LF was not suspected at initial assessment. The term probable is important because absence of documentation does not prove that the clinician did not consider LF. Delayed suspicion was defined as a documented delay of more than 24 hours before LF suspicion or specimen collection.

Qualitative Participants and Data Collection

Nine identifiable interviews were analyzed. Participants included two state-level public-health leaders, two LGA surveillance officers and five facility-based informants from tertiary, secondary, primary and private care. One intended participant did not have a separately identifiable transcript and was not reconstructed. Interviews explored LF knowledge, differentiation from malaria, missed cases, diagnostic tools, training, notification, surveillance, co-infection, patient outcomes and recommendations.

Participants gave recorded verbal consent and transcripts were de-identified using participant codes. Quotations were edited only lightly to remove repeated words and improve readability while preserving their substantive meaning.

Quantitative and Qualitative Analysis

Categorical variables were summarized using frequencies and percentages. Age was described using the mean, standard deviation, median and range after restriction to plausible values. Pearson chi-square tests examined bivariate associations. A multivariable binary logistic regression model for probable missed LF suspicion included year, facility type, residence, LF diagnostic capacity, malaria-test positivity and previous malaria treatment. Adjusted odds ratios, 95% confidence intervals and two-sided p values were reported. Because the facility and LGA strata were purposively selected and some cells were sparse, estimates were interpreted as sample-specific associations rather than population trends.

Qualitative data were analyzed using reflexive thematic analysis [18]. Coding focused on recurring clinical and health-system patterns, contradictions and differences across stakeholder levels. Theme counts represent the

number of nine transcripts containing substantive evidence for each theme. They are presented for analytic transparency and not as statistical prevalence.

Integration occurred after separate analyses. Quantitative associations were compared with qualitative explanations to identify convergence, complementarity and divergence. The purpose was to determine not only whether a statistical pattern was present but also how it could arise in routine practice.

Ethics and Reporting

The retrospective records were de-identified. Interview participation was voluntary and based on recorded consent. The final journal version should insert the exact approving ethics committee, approval number and approval date from the approved study documents. The quantitative reporting was prepared with reference to STROBE and the qualitative reporting with reference to COREQ [19, 20].

Results

Characteristics of the Analytic Sample

In Table 1 below, the analytic dataset contained 463 records. The mean age was 37.8 years (SD 20.2), the median was 35 years and the observed range was 0–91 years among records with plausible ages. Females accounted for 239 (51.6%) records and males for 224 (48.4%). Owo contributed 327 (70.6%) records. This concentration reflects the purposive inclusion of high-burden facilities and should not be interpreted as the population distribution of LF in the state.

Table 1. Selected Characteristics of the Retrospective Analytic Sample (N = 463, Mean Age = 37.8 years, Median Age = 35 years and Observed Range = 0–91 years)

Characteristic	n	%
Female	239	51.6
Male	224	48.4
Age <15 years	53	11.5
Age 15–24 years	78	16.9
Age 25–44 years	161	34.9
Age ≥45 years	169	36.7
Tertiary facility	339	73.2
Secondary facility	25	5.4
Primary health-care facility	51	11.0
Private facility	48	10.4
Urban residence	397	85.7
Rural residence	66	14.3
Year 2021	116	25.1
Year 2022	149	32.2
Year 2023	198	42.8

Clinical Presentation and the Initial Diagnostic Pathway

The Table 2 below shows fever was recorded in 453 (97.8%) records. Headache occurred in 214 (46.2%), weakness in 134 (28.9%) and body pain in 112 (24.2%). Bleeding was recorded in only 15 (3.2%) records. The clinical picture was therefore dominated by non-specific symptoms rather than by a classic haemorrhagic presentation.

Malaria was suspected in 440 (95.0%) records and a malaria test was documented in

438 (94.6%). Rapid diagnostic testing accounted for 365 (78.8%) recorded malaria tests and microscopy for 63 (13.6%). Malaria treatment was recorded in 302 (65.2%) records. LF was suspected at first contact in 262 (56.6%) records and was not suspected in 201 (43.4%).

Table 2. Clinical Presentation, Diagnostic Pathway and Missed-Detection Indicators (N = 463)

Indicator	n	%
Symptom		
Fever	453	97.8
Headache	214	46.2
Weakness	134	28.9
Body pain	112	24.2
Vomiting	84	18.1
Diarrhoea	62	13.4
Joint pain	41	8.9
Bleeding	15	3.2
Diagnostic pathway		
Malaria suspected	440	95.0
Malaria test documented	438	94.6
Malaria result positive	304	65.7
Malaria treatment given	302	65.2
LF suspected at first contact	262	56.6
LF test requested	461	99.6
Missed/delayed detection		
Probable missed LF suspicion	103	22.2
Documented delay >24 hours	33	7.1
Previous malaria treatment before LF confirmation	324	70.0
Symptoms persisted after malaria treatment	359	77.5

Laboratory Confirmation, Co-Infection and Probable Missed Suspicion

All the purposively selected 463 records were confirmed positive with LF laboratory result. Direct cross-classification of the LF and malaria laboratory fields identified 297 patients positive for both infections. These 297 records represented 64.1% of the 463 laboratory-confirmed LF records. The dedicated co-infection variable classified 311 (67.2%) records as confirmed co-infection, but the direct laboratory definition was retained for the main analysis because it was biologically more explicit.

A total of 103 records (22.2%) met the probable missed-suspicion definition. From the analysis, 103 records were drawn from the confirmed LF sample and 77 (74.8%) were malaria-positive. Five were LF-negative, one had testing not done and one had no recorded LF result. The finding indicates that the missed-

suspicion measure frequently preceded later LF confirmation.

The recorded proportion of probable missed suspicion of LF was 5.2% in 2021, 14.8% in 2022 and 37.9% in 2023 – an increasing trend that is quite worrisome (Figure 1). Because facility composition and abstraction coverage varied by year, these values should rather not be interpreted as a statewide temporal trend. They show instead that probable missed-suspicion records were concentrated in the later part of the selected analytic sample.

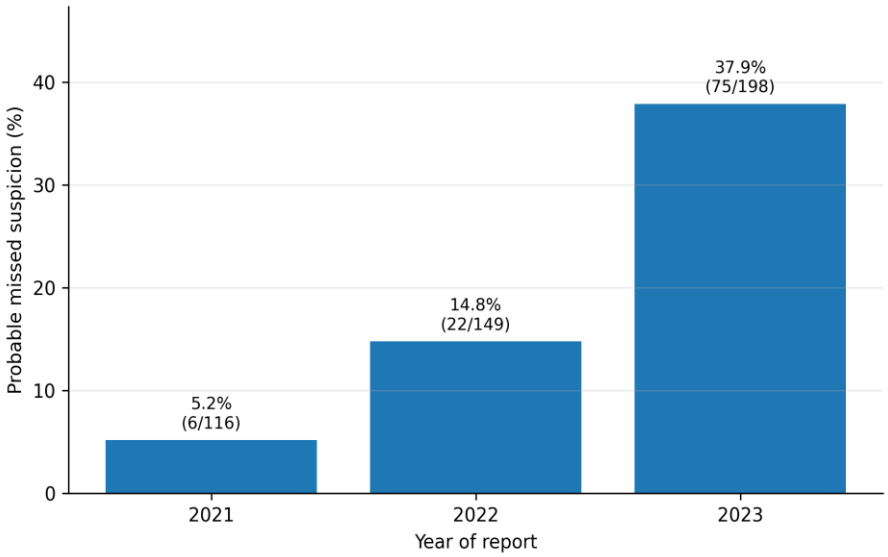


Figure 1. Probable Missed Lassa Fever Suspicion by Year of Report

Percentages use all linked records within each year. Facility composition and abstraction coverage varied over time.

(Originally created by me – Saiki Adinoyi Musa)

Factors Associated with Probable Missed LF Suspicion

At bivariate level shown in Table 3, probable missed suspicion was associated with LGA, facility type, first point of care, residence, occupation, year, recorded LF diagnostic capacity, malaria positivity and previous malaria treatment. Age group, sex and education did not meet the 5% significance threshold. The stronger pattern across service and diagnostic variables than across basic demographic variables points towards a health-system and case detection-pathway explanation.

Table 3. Bivariate Associations with Probable Missed LF Suspicion

Factor	χ^2	df	p-value
Age group	0.626	3	0.891
Sex	0.005	1	0.941
Local government area	41.903	4	<0.001
Facility type	56.434	3	<0.001
First point of care	12.788	4	0.012
Residence	4.748	1	0.029
Education	7.172	3	0.067
Occupation	12.798	5	0.025
Year of report	52.344	2	<0.001
LF diagnostic capacity	11.611	1	<0.001

Malaria-test positivity	4.358	1	0.037
Previous malaria treatment	4.216	1	0.040

In the adjusted model shown in Table 4, malaria-test positivity remained associated with probable missed LF suspicion (aOR 5.30, 95% CI 2.13 – 13.19; $p < 0.001$). Compared with 2021, the odds were higher in 2022 and 2023. Primary health-care records had lower adjusted odds than tertiary-facility records in the selected sample. Private-facility estimates approached the conventional threshold but did not reach statistical significance. Previous malaria treatment was not independently associated with missed suspicion after adjustment. The large year effects and wide confidence intervals in some strata indicate sparse-cell instability and should not be interpreted as evidence of a secular statewide increase.

Table 4. Multivariable Logistic Regression for Probable Missed LF Suspicion

Predictor	**Comparison**	**aOR**	**95% CI**	**P**
Year	2022 vs 2021	4.07	1.55–10.68	0.004
	2023 vs 2021	29.39	10.93–79.06	<0.001
Facility	Secondary vs tertiary	1.19	0.43–3.28	0.739
	PHC vs tertiary	0.07	0.01–0.52	0.010
	Private vs tertiary	2.43	0.99–5.96	0.052
Residence	Urban vs rural	0.68	0.33–1.40	0.293
LF capacity	No vs yes	2.07	0.67–6.42	0.208
Malaria test	Positive vs non-positive	5.30	2.13–13.19	<0.001
Previous malaria treatment	Yes vs no	1.02	0.42–2.45	0.968

Patient Outcomes

Overall, 386 (83.4%) patients recovered, 53 (11.4%) died, 20 (4.3%) were referred and four (0.9%) had unknown outcomes. Among the 463 laboratory-confirmed LF records, 53 deaths yielded an observed case-fatality proportion of 11.4%. This is a sample-specific case-fatality proportion and not a population case-fatality rate because the analytic sample was purposively assembled.

In an exploratory unadjusted comparison restricted to laboratory-confirmed LF records, death occurred in 46 of 297 co-infected records (15.5%) and six of 106 records without a positive malaria result (5.7%). The crude odds ratio was 3.05 (95% CI 1.26–7.38; Fisher exact $p = 0.011$). This comparison is hypothesis-generating. The dataset did not adequately adjust for diagnostic delay, referral severity, comorbidity, viral load, dehydration, treatment timing or facility selection. The result therefore does not establish that malaria independently caused excess mortality.

Qualitative Findings

As shown in Table 5, nine interviews were analysed. Participants occupied different positions in the detection system, but their accounts converged on a common problem: early LF often looks ordinary, while malaria is familiar and easy to test. The resulting pathway was not described as the consequence of a single clinician error. Participants linked missed detection to symptom ambiguity, malaria-first routines, access to testing, specimen transport, surveillance relationships, patient movement between providers and uneven training.

Table 5. Themes Derived from Key-Informant Interviews

Theme	Participants	Analytic Meaning
Symptom overlap and early diagnostic ambiguity	9/9	Early LF resembled malaria through fever, headache, weakness, vomiting, diarrhoea and body pain. Bleeding or facial swelling was often described as a later signal.
Malaria-first diagnostic pathway and masking	9/9	Malaria was commonly considered first. A positive result could reduce suspicion for LF and redirect attention to antimalarial treatment.
Delayed suspicion after treatment failure or repeat visits	8/9	LF was often reconsidered after 24–72 hours of non-response, repeated treatment, discharge and return or another point-of-care encounter.
Restricted RT-PCR access, specimen transport and turnaround	9/9	Malaria RDTs were more accessible, whereas LF confirmation depended on centralized molecular testing, transport, cold chain, cost and turnaround.
Knowledge, experience and refresher-training gaps	9/9	Training existed but coverage was uneven. Staff movement and limited co-infection-specific content created a continuing need for practical retraining.
Surveillance notification and communication gaps	7/9	Late clinician notification, weak facility–DSNO links, workload and limited reporting tools delayed surveillance action.
Patient-level barriers and delayed care seeking	7/9	Self-treatment, patent medicine vendors, traditional remedies, stigma, distance and transport costs lengthened the pre-diagnostic journey.
Co-infection affected detection more consistently than prognosis	8/9	Participants agreed that co-infection could obscure or delay diagnosis but differed on whether malaria independently worsened outcomes once both infections were treated.
Priority interventions	9/9	Participants prioritized recurrent training, visible algorithms, active case search, specimen transport, decentralized testing, clinician–surveillance networks and community education.

Excerpts from Frontline and Surveillance Narratives

"There are several instances where you think it is malaria initially. You treat the patient for malaria. Sometimes we even discharge the patient. But then the patient returns, not getting better; instead, the patient is getting worse."

PID-01-001, state public-health leader

The excerpt captures the central trajectory identified in the interviews. LF suspicion often developed after the malaria pathway had already begun. The problem was not necessarily the initial decision to test or treat malaria. The missed opportunity arose when persistent illness did not trigger an earlier parallel consideration of LF.

"At presentation, we did a malaria test and it was positive, so every attention was focused on malaria. It was when the patient had received antimalarial and other

medication for two days without response that we thought about Lassa fever.

PID-04-007, secondary-facility focal clinician

This account illustrates how a positive malaria result can become a stopping point in clinical reasoning. It also explains why treatment failure emerged repeatedly in the qualitative data as a practical trigger for LF suspicion.

"Some may feel that since this person is positive for malaria, there is no need to suspect Lassa. On a good day, it should not be so."

PID-02-004, local-government surveillance officer

The statement is particularly important for interpreting the quantitative association between malaria positivity and probable missed suspicion. It points to a change in the meaning attached to the malaria result rather than to a problem with malaria testing itself.

"That timely response is still bound to the transportation of the sample. If you remove that impediment, every other thing can move. That is a major problem."

PID-04-007, secondary-facility focal clinician

Once LF suspicion was raised, the next delay could occur outside the consulting room. Sample transport, packaging, refrigeration, weekend schedules, consumables and communication with surveillance teams were repeatedly described as practical constraints.

Discussion

Principal Findings

The central finding of this study is that the relationship between malaria and LF in the selected Ondo State facilities is not limited to biological co-occurrence. It also operates through the diagnostic pathway. Among 463 laboratory-confirmed LF records, 297 had positive malaria and LF laboratory results in the same record. This 64.1% proportion is higher than the 37% reported in an earlier Nigerian conference series [5]. The difference should not be interpreted as evidence of a statewide increase. The present estimate comes from a purposively selected linked-record sample, a different period and a direct laboratory definition of co-infection.

The study's more important contribution is the link between co-infection and detection. Probable missed LF suspicion occurred in 103 of 463 records (22.2%), and 96 of those records were later LF laboratory-positive. Malaria positivity remained associated with missed suspicion after adjustment, with approximately fivefold higher odds. The qualitative strand gave this statistical finding a clinical sequence: fever was interpreted as malaria, malaria was tested or treated, the positive result could reinforce the initial explanation, and LF was reconsidered when the expected response did not occur.

This interpretation is consistent with evidence that early LF is difficult to distinguish from other febrile illnesses [7, 8]. It also fits the concept of premature diagnostic closure described by Croskerry [13]. The present study adds a setting-specific explanation. In a malaria-endemic environment, diagnostic closure does not necessarily arise because clinicians lack knowledge of LF. It can arise because the common diagnosis is plausible, rapidly testable and reinforced by the clinical routine.

The study also found that 70.0% of records had previous malaria treatment before LF confirmation and 77.5% documented persistence of symptoms after malaria treatment. The qualitative accounts were closely aligned with these figures. Eight of nine participants described reconsideration after non-response, repeated attendance or deterioration. Treatment failure therefore appears to function as a practical trigger for LF suspicion. The concern is that waiting for that trigger consumes time.

Co-Infection as a Diagnostic-Masking Mechanism

The high co-infection proportion within the selected analytic sample supports the need to treat malaria and LF as potentially concurrent diagnoses in endemic facilities. Earlier Nigerian evidence identified malaria parasitemia among confirmed LF cases [5, 21]. Studies in Ondo State have also reported LF–malaria co-infection and clinical severity concerns [5]. The present study extends this evidence by showing that co-infection can matter before treatment outcomes are considered. It can affect the route through which LF is recognized.

Rugarabamu et al. (2022) reported the difficulty of distinguishing malaria from viral haemorrhagic fevers when clinical presentations overlap. The qualitative evidence in the present study provides a similar account from routine care. Participants repeatedly described fever, headache, weakness, vomiting and body pain as features that could support a malaria diagnosis without excluding LF. The absence of bleeding at early presentation is also relevant. Only 3.2% of records documented bleeding, suggesting that reliance on haemorrhagic features alone would miss much of the clinically difficult presentation.

The implication is not to replace malaria-first probability with indiscriminate LF testing. Such an approach would be inefficient and difficult to sustain. The more defensible response is to prevent malaria confirmation from becoming a diagnostic stopping rule. The clinical question should change from “Is this malaria?” to “Does malaria fully explain this illness, given the clinical course and epidemiological context?”

Malaria Positivity and Missed LF Suspicion

Malaria-test positivity was the strongest independent diagnostic-pathway association in the adjusted model. Patients with positive malaria results had higher odds of probable missed LF suspicion. This finding is consistent with the qualitative theme of malaria-first reasoning, which was present in all nine interviews. Participants described situations in which the positive malaria result appeared to settle the diagnosis until the patient failed to improve.

The result should be interpreted carefully. A positive malaria test is not itself a diagnostic error. The study does not show that malaria testing should be reduced or that antimalarial treatment caused LF to be missed. Instead, the result suggests that malaria positivity changes the clinical context in which LF is considered. The distinction matters because the practical intervention is not to remove malaria from the pathway. It is to keep the LF pathway open when risk persists.

The finding is also compatible with earlier observations that malaria and LF share overlapping clinical features and that diagnostic schemes for viral haemorrhagic fevers must account for common febrile illnesses [22]. In this study, the strongest quantitative signal came from malaria positivity, while the qualitative accounts explained the cognitive and operational process behind it.

Rural Residence, Access and the Accumulation of Delay

Rural residence was associated with delayed LF suspicion in the thesis analysis. Although it did not remain an independent predictor of probable missed suspicion in the reconciled adjusted manuscript model, the direction of the evidence remains relevant. The qualitative data identified structural barriers that help explain why location can prolong the diagnostic pathway.

Participants described centralized PCR testing, specimen-transport costs, transport delays, cold-chain requirements, shortages of consumables and difficulty accessing testing centres. These barriers are consistent with the wider Nigerian literature on delayed LF recognition and presentation [2-4, 23]. The issue is therefore not simply whether a clinician

knows LF. A knowledgeable clinician still faces delay if the facility lacks a functioning route from suspicion to sample collection, transport and result.

The findings also fit Donabedian's structure–process–outcome perspective. Diagnostic capacity, trained personnel and transport arrangements are structural conditions. Clinical reassessment, notification and specimen referral are processes. Missed suspicion and delayed confirmation are outcomes of that system. Improving one component without the others is unlikely to remove the entire delay.

Healthcare-Worker Knowledge, Experience and Clinical Reasoning

The interviews showed that healthcare workers generally recognized LF but did not always apply suspicion early in the case detection pathway. Training existed, yet participants described uneven coverage, staff turnover and a continuing need for practical refresher training. This is consistent with previous evidence of knowledge gaps among healthcare workers in Ondo State [1, 15, 24].

The findings suggest that training should move beyond factual awareness. Healthcare workers need to practice decisions that are likely to occur in real consultations. They need to recognize when malaria and LF should be considered together, how to interpret a positive malaria result without closing the differential, when persistent fever should trigger reassessment and how to activate sample collection and notification.

This is why a visible case-detection algorithm is important. Knowledge that remains in training materials but is not available at the point of care is less likely to influence a time-pressured decision. The qualitative participants themselves prioritized visible algorithms, recurrent training, active case search and stronger clinician–surveillance links.

Treatment Pathways and Repeated Healthcare Visits

Previous malaria treatment was common before LF confirmation, and most records documented persistence of symptoms after treatment. In the thesis analysis, some treatment variables, including ACT and adjunct care, showed associations with missed LF cases. The adjusted manuscript model did not retain previous malaria treatment as an independent predictor. This apparent difference is important. It suggests that treatment variables are better interpreted as markers of the clinical decision pathway than as pharmacological causes of missed LF detection.

The qualitative accounts support this interpretation. Participants described escalation from oral antimalarials to injectable therapy and repeated treatment before LF was considered. The practical problem is the time consumed while the diagnosis remains anchored on malaria. When the patient returns after treatment failure, the opportunity for earlier LF suspicion has already been lost.

This pattern also explains why repeated healthcare visits matter. The patient may move between public and private facilities, patent medicine vendors and other providers before reaching a facility with LF diagnostic capacity. One private-facility informant captured the patient-side component: "One thing that prevents early diagnosis is the patient factor. They keep treating the so-called malaria and typhoid illness before they come." The diagnostic pathway therefore begins before the patient reaches the LF-capable facility.

Patient Outcomes and the Limits of Causal Interpretation

The observed case-fatality proportion among laboratory-confirmed LF records was 11.4%. Death was more frequent among co-infected records in the unadjusted comparison. This finding is compatible with earlier reports that LF severity and outcomes are influenced by timing of presentation and clinical care [2, 4].

However, the present study cannot establish that malaria independently caused mortality.

The outcome comparison did not adequately control for diagnostic delay, viral load, organ dysfunction, comorbidity, dehydration, referral severity or treatment timing. The qualitative participants also differed in their views about whether malaria independently worsened prognosis after both infections were recognized and treated. The more defensible interpretation is therefore that co-infection affected detection more consistently than it demonstrated an independent causal effect on mortality.

A prospective cohort would be needed to test whether malaria mediates outcome through delayed LF recognition. Such a study should measure malaria parasite burden, LF viral load, clinical severity, time from symptom onset to presentation, time to LF suspicion, time to specimen collection, time to treatment and subsequent outcomes.

Mixed-Methods Integration

The two strands converged around a diagnostic-masking mechanism. Quantitatively, 22.2% of records met the probable missed-suspicion definition, 70.0% had previous malaria treatment and malaria positivity was associated with more than fivefold higher adjusted odds of missed suspicion. Qualitatively, participants reconstructed the sequence behind those numbers. Malaria was considered first. A positive result could appear reassuring. LF was reconsidered after non-response, repeat attendance or deterioration.

The health-system findings also converged. Facility type, LGA, first point of care and recorded diagnostic capacity showed quantitative associations at the bivariate level, while interviews described centralized RT-PCR, transport costs, cold-chain requirements, staff turnover, notification delays and uneven reporting tools. There was a meaningful divergence on outcomes. The quantitative data showed a crude association between co-infection and death, but the interviews did not establish that malaria independently worsened prognosis after both conditions were treated (See Table 6).

Table 6. Joint Display Integrating Quantitative and Qualitative Findings

Domain	Quantitative Evidence	Qualitative Explanation	Integrated Implication
Malaria positivity and missed suspicion	aOR 5.30 (95% CI 2.13–13.19)	Positive malaria results could reduce consideration of LF.	Treat malaria, but retain an LF trigger when risk persists.
Treatment failure and repeat attendance	70.0% had previous malaria treatment; 77.5% had persistent symptoms.	LF was often reconsidered after 24–72 hours, repeat visits or deterioration.	Reassess early and collect LF specimens when indicated rather than waiting for repeated failure.
Diagnostic infrastructure	Missed suspicion varied by facility, first point of care, LGA and diagnostic capacity.	Centralized RT-PCR, transport, cold chain, cost and turnaround were recurring barriers.	Strengthen transport, consumables, turnaround and decentralized capacity where feasible.
Surveillance and workforce	Facility and geographic patterns were stronger than age/sex effects.	Staff turnover, uneven refresher training and weak clinician–DSNO links recurred.	Link training to named surveillance contacts, feedback and active case search.

Outcome	Observed LF case-fatality proportion 11.4%; crude mortality higher with co-infection.	Participants agreed on diagnostic delay but not an independent prognostic effect of malaria.	Treat mortality comparison as exploratory; test causality prospectively.

Proposed Integrated LF–Malaria Case Detection Algorithm for Endemic Settings

The study findings support a facility-level algorithm designed around the main point at which diagnostic masking occurred in the current case detection pathway as shown in Figure 2. The proposed algorithm, shown in Figure 3, does not ask healthcare workers to abandon malaria testing. It introduces a parallel LF pathway whenever the clinical or epidemiological picture remains compatible with LF.

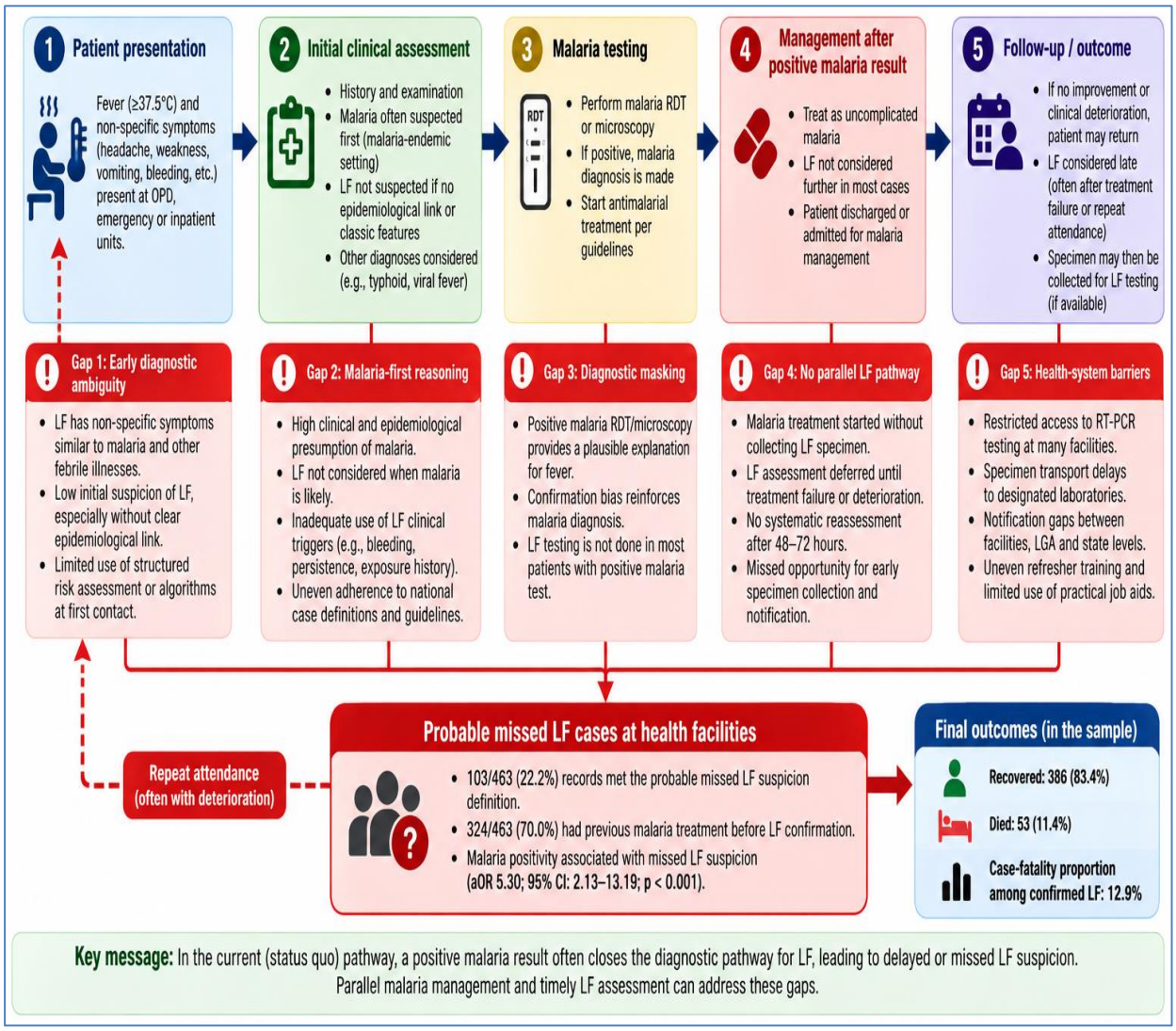


Figure 2. Current Status of Lassa Fever Case Detection Pathway in Endemic Health Facilities Showing Key Gaps that Allows Probable Missed LF Cases

(Originally created by me – Saiki Adinoyi Musa)

https://doi.org/10.21522/TIJAR.2014.13.04.Art024

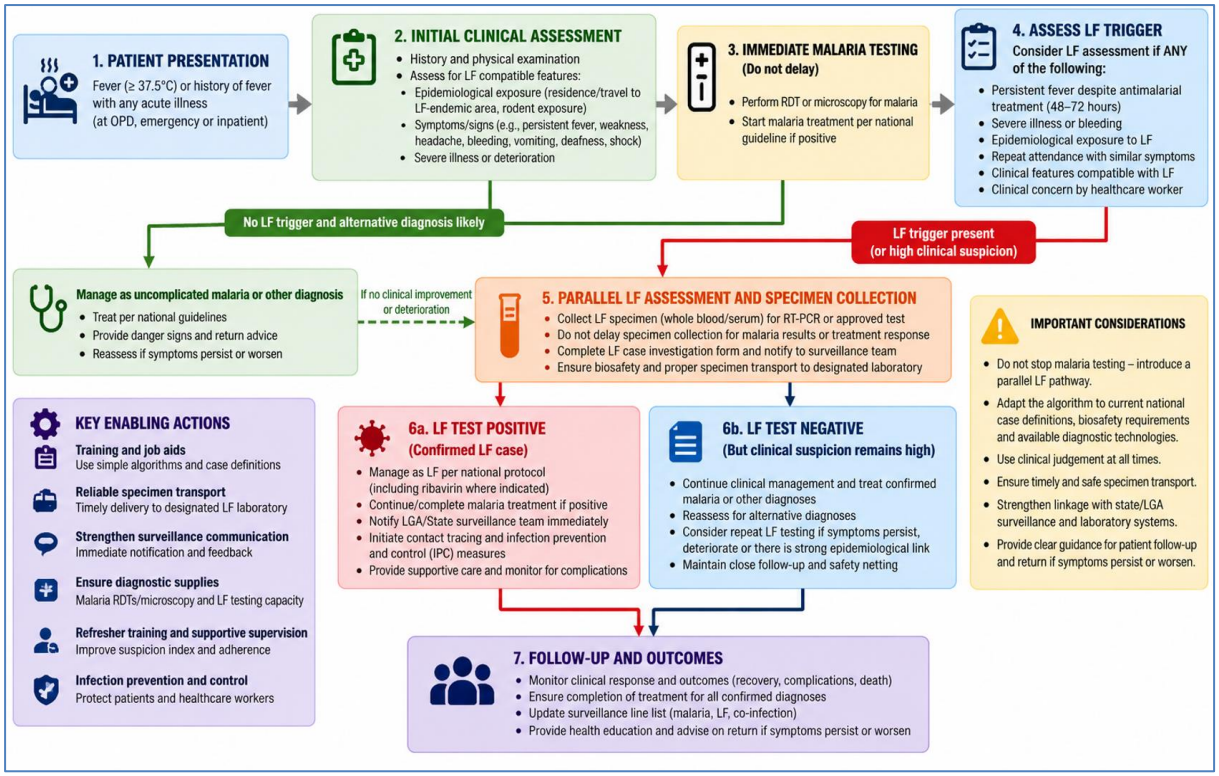


Figure 3. Proposed Integrated LF–Malaria Case-Detection Algorithm for Endemic Health Facilities

(Originally created by me – Saiki Adinoyi Musa)

Implications for Clinical Practice and Surveillance

The proposed pathway responds directly to the study's most consistent finding: malaria confirmation should not automatically close the LF diagnostic process. In practice, this means that a patient with a positive malaria result and persistent fever should not necessarily receive another course of malaria treatment without reassessment. The clinician should ask whether the clinical course remains compatible with LF and, where the trigger is met, collect the LF specimen promptly.

Implementation requires more than placing an algorithm on a wall. Facilities need appropriate sample-collection materials, clear notification channels, reliable specimen transport, feedback from laboratories and continuous training. State and LGA surveillance teams should also use active case search as a learning mechanism. Reviewing missed trajectories with facility teams can show where suspicion, notification or sample collection was lost.

Private hospitals and other first-contact providers should be included in the pathway. The qualitative data showed that patients may move through multiple providers before LF is suspected. A diagnostic strategy that operates only inside public LF treatment centres will therefore miss part of the patient journey. Referral and notification links should extend to private facilities and, where appropriate, community-level referral actors.

Strengths and Limitations

The study has several strengths. It linked LF surveillance, outpatient, malaria and laboratory records across different levels of care. It used a conservative direct laboratory definition of co-infection. It distinguished probable missed suspicion from confirmed LF. It also included state, LGA and facility-level participants, allowing the qualitative strand to explain the operational setting behind the statistical findings. The joint display made convergence

and divergence explicit rather than treating qualitative evidence as a supplementary narrative.

Several limitations warrant caution in interpreting these findings. The retrospective design depended on the completeness and accuracy of registers and case notes. Purposive selection of confirmed LF records with linked malaria information introduced selection bias, limiting representativeness and preventing the observed 64.1% co-infection proportion from being interpreted as statewide prevalence. This selection may also have biased the adjusted association between malaria positivity and probable missed LF suspicion (aOR 5.30). Because the direction and magnitude of this bias cannot be established from the available data, the estimate should be interpreted as an association within the selected analytic sample rather than a population-level effect. The dataset also contained inconsistent labels, duplicate export fields, two implausible age values and some missing laboratory information. The dedicated co-infection field did not fully agree with direct laboratory cross-classification.

The probable missed-suspicion outcome relied on documented fulfilment of the study's case definition and recorded clinical suspicion; undocumented clinical reasoning may therefore have led to misclassification. Uneven facility and LGA representation produced sparse cells and potentially unstable estimates in some regression categories. One intended qualitative participant lacked a separately identifiable transcript, while recall and social-desirability bias may have influenced interview accounts. Finally, the observational design cannot establish that malaria positivity caused missed LF suspicion or mortality. These limitations should be considered when interpreting the findings and assessing their transferability to other facilities and populations.

Conclusion

This study shows that LF–malaria co-infection is common within the selected linked records from high-burden facilities in Ondo State and that the significance of co-infection extends beyond biological overlap. Malaria can influence the way LF is recognized. The clearest signal was the association between malaria positivity and probable missed LF suspicion. The qualitative findings explain how this can happen in practice. Fever is often approached as malaria, a positive result can reinforce that decision and LF is reconsidered when the patient fails to improve, deteriorates or returns.

The findings also show that detection does not depend on clinical reasoning alone. Rural access, diagnostic infrastructure, specimen transport, surveillance communication and healthcare-worker training shape what happens after the patient enters the health system. The study therefore points to a practical change in approach. Malaria should continue to be tested and treated, but a positive malaria result should not close the LF pathway when clinical or epidemiological risk remains. Earlier parallel assessment, prompt LF specimen collection, reliable specimen movement and continuous clinical learning offer a realistic route to reducing missed opportunities.

Recommendations

State Ministry of Health

The Ondo State Ministry of Health should adopt and pilot the proposed integrated LF-malaria case-detection algorithm in high-burden facilities. The algorithm should be incorporated into routine fever assessment rather than reserved for declared outbreaks. The State Epidemiologist and State DSNO should coordinate its implementation with clinical leadership, laboratory services and LGA surveillance teams.

The state should establish a dependable LF specimen-transport system with defined

collection schedules, weekend coverage where needed, appropriate cold-chain arrangements, tracking and clear turnaround targets. Diagnostic strengthening should also include adequate consumables and progressive expansion of molecular testing or validated near-patient options where feasible and safe.

The Ministry should institute recurrent, case-based training for healthcare workers. Training should use real diagnostic trajectories and focus on symptom overlap, co-infection, interpretation of malaria-positive results, treatment failure as a reassessment signal, specimen collection and notification. Training should be linked to named facility surveillance focal persons so that knowledge is connected to action.

The state should strengthen routine monitoring of the diagnostic pathway itself. Surveillance should track not only confirmed LF cases but also time from first presentation to suspicion, notification, specimen collection and confirmation. These indicators would allow the system to identify where delay is accumulating.

Local Government Area level

LGA DSNOs and their assistants should provide supportive supervision to public and private facilities, with particular attention to facilities that serve as first points of contact. Supervisory visits should review whether LF triggers are recognized, whether suspected cases are notified promptly and whether specimens move through the referral system without avoidable delay.

LGA surveillance teams should maintain active case search and use missed trajectories as learning material. When a confirmed LF case is identified, the team should review where the patient first presented, whether malaria was considered, when LF entered the differential, when the specimen was collected and whether notification was timely. The purpose should be improvement rather than blame.

Community and provider communication should also be strengthened. Patients who repeatedly receive treatment for malaria without improvement should be encouraged to return promptly or seek referral. Private clinics and patent medicine vendors should be linked to referral and notification messages because the qualitative findings show that patients often move through these points before reaching LF-capable facilities.

Health-Facility Level

The health facility is the primary intervention point arising from this study. LF focal doctors or nurses, case managers, facility surveillance focal persons, medical officers in private hospitals and Officers-in-Charge of PHCs should use the integrated algorithm as part of routine fever assessment. A malaria-positive result should not automatically terminate LF assessment where fever persists, illness is severe or unusual, epidemiological risk is present, the patient returns after treatment or clinical improvement does not occur within the defined reassessment period.

Where the LF trigger is met, the facility should collect the LF specimen promptly while continuing appropriate malaria care. Notification should occur at the same time. The facility surveillance focal person should maintain a direct communication line with the LGA DSNO and ensure that specimen movement and laboratory feedback are documented.

Facility leaders should incorporate short LF-malaria case reviews into routine clinical meetings. These reviews should examine missed opportunities without assigning individual blame. They should ask simple operational questions: Was LF considered early? Did the malaria result close the differential? Was the LF specimen collected promptly? Was notification made? Did the sample move? Was the result returned to the clinician?

Private facilities should receive the same algorithm, training and referral support as public facilities. This is essential because a

patient can enter the diagnostic pathway outside the public health system and return later with more advanced disease. The study's qualitative findings make this patient movement an important part of the intervention rather than a peripheral issue.

Ethics Approval and Consent to Participate

This work was approved by the Ondo State Health Research Ethics Committee (OSHREC), with assigned number NHREC/Ondo SMH-HREC/02/01/2025 and protocol number OSHREC/18/05/2026/13/05. The retrospective records were de-identified and interview participants provided recorded consent.

Consent for Publication

No personally identifiable information (PII) of any case is reported. Participant quotations are presented using study codes.

Data Availability

The de-identified analytic dataset and coding framework will be made available only in accordance with Ondo State Ministry of Health, participating-facility and applicable data-governance requirements.

Conflict of Interests

All authors declares no conflict of interest.

Funding

This study was funded from personal savings and received no specific external funding.

Author Contributions

- Conceptualization and Methodology: Saiki Adinoyi Musa
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- Writing of first draft: Saiki Adinoyi Musa
- Manuscript Review: All authors

Acknowledgements

My profound gratitude goes to the *Ondo State Ministry of Health* who through its ethical review committee provided me the opportunity carry out this study on its tuft and ensuring that I receive the utmost cooperation the study so deserve. I also sincerely appreciate my research team, ably led by *Dr Stephen Fagbemi*, the then Ondo State Director of Public Health, and *Mr Gboyega Famokun*, the Ondo State Disease Surveillance and Notification Officer (SDSNO). I am equally grateful to my research assistants, *Faith Oluwatosin Songodale, Bukola Bale, and Mathew Oluwole*, as well as the LGA Disease Surveillance and Notification Officers (DSNOs) of *Akure North, Akure South, Akoko Southwest, Ose, and Owo Local Government Areas*. Your resilience, commitment, cooperation, and dedication before, during, and after the data collection process were instrumental to the successful completion of this study. I sincerely appreciate every effort you contributed.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art025

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Pathways to Sexual and Reproductive Health Empowerment among Adolescent Girls in a Resource-Constrained Setting: A Grounded Theory from Southwest Cameroon

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Cite this article as: Binsila Bernard Benjika, Nana Celestin, Bodzewan EF. Pathways to sexual and reproductive health empowerment among a dolescent girls in a resource-constrained setting: a grounded theory from Southwest Cameroon. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art025**

Received: 18.08.2026
Accepted: 06.10.2026
Published: 30.10.2026

Article Type: Original Research

Abstract *Adolescents' journey toward Sexual and Reproductive Health Empowerment (SRHE) in many sub-Saharan African countries faces myriad hurdles. This study aimed to describe pathways to SRHE among Adolescent Girls in a resource-constrained setting in Cameroon's Southwest Region, which has been affected by a socio-political crisis since 2016. The study obtained ethical approval and used a concurrent triangulation and sequential exploratory mixed-methods design within a survey framework, combining quantitative and qualitative approaches. The study included 465 participants: adolescent girls, parents, health personnel, and key informants from traditional, educational, health, social, legal, women and gender empowerment, UN organizations, and civil society organizations. Researchers analyzed quantitative data using SPSS, while qualitative data underwent thematic analysis using ATLAS.ti and NVivo. The findings revealed that though adolescent girls were empowered, the impact was questionable as they still engaged in sex relatively early. Though they were generally aware and had access to either form of contraceptive methods, their willingness to use them was relatively low except for condoms. Among others, teenage pregnancy was relatively high. Critical predictors of early sex were the poverty / economic emancipation, the vulnerability of those with dead parents, from a single-mother home, or living with a friend, and the conflict and fragility context. To improve and sustain SRHE, stakeholders suggested early home-based education; comprehensive/intensified school-based education; intensified community-based education and awareness; and education through controlled mass media. SRH education mostly started in early adolescence.*

Keywords *Adolescent Girl, Cameroon, Empowerment, Grounded Theory, Pathway, Resource-Constrained Setting, Southwest, SRH.*

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Introduction

The pathway of adolescent girls to Sexual and Reproductive Health (SRH) empowerment in many sub-Saharan African countries is not without a myriad of hurdles. These hurdles vary in dimensions, including socio-cultural, institutional, and personal factors. At home, in schools, and in the community, young adolescent girls face transformational and developmental challenges in acquiring the knowledge and practical skills needed for a healthy SRH life. The negative outcomes deriving from unsuccessful SRH emancipation are enormous, among which are unwanted pregnancies, STIs, school dropouts, unsafe abortions, morbidities, deaths, and the overall repercussions on socio-economic development at individual, micro, and macro levels. In Sub-Saharan Africa, adolescents make up a significant share of the global population, accounting for about 23 percent [1]. Adolescence is a critical age in which people undergo multifaceted sexual development [2]. Sundry health risks and complications secondary to unprotected sexual activity among adolescents have been reported and documented by the World Health Organization [3, 4], for which urgent and prompt interventions are recommended. Recent data indicate that 1.2 billion people worldwide are adolescents aged 10–19 years [5]. Adolescents are slightly at an increased level of vulnerability for different health conditions, including sexually transmitted diseases, when compared to the adult population [6]. Risky sexual behavior is characterized by different hazardous behaviors ranging from premarital sex and multiple sexual partners to unprotected sex. Such hazardous sexual behaviors are reported to end up with unpleasant health outcomes like HIV/AIDS, unwanted pregnancies, unsafe abortions [7], and other STIs. Teenage motherhood remains a crucial public health problem that especially affects their mental health, with depression and anxiety disorders considered among the most disabling mental health problems for 1/8 teenage mothers worldwide [8]. It is estimated that 16 million girls aged 10–19 years give birth every year, accounting for almost 11% of all births worldwide [9], with this early and generally unwanted childbearing remaining persistently detrimental to the mental health of teenagers in the world and mostly in developing countries, especially those facing internal conflicts like Cameroon [10]. The South-West region, as of December 2023, has 41912 estimated number of people living with HIV (SPECTRUM; a statistical software used by the National AIDs Control Committee, 2023). This is coupled with the socio-political crisis in the region, which has brought in a lot of internally displaced persons (IDPs) and has also led to high sexual promiscuity, exposing adolescent girls to a high risk of HIV/AIDS and other STIs. Despite its illegality in Cameroon, induced abortion is still practiced, whereas this is prohibited by the Reproductive Health Services Policy (2009). In 2015, in the obstetrics and gynecologic services in Yaounde, Cameroon, the prevalence of voluntary induced abortion was 26.3% (134/509) globally; 25.6% (65/254) in urban areas and 27.1% (69/255) in rural areas, with many suffering from excessive bleeding as the main risk [11]. It was reported that unsafe abortion accounts for 13% of maternal deaths [1], and 20% of the total mortality and disability burden due to pregnancy and childbirth [12]. An early study in Tiko Health District revealed that having multiple sexual partners was a risk factor for the prevalence of teenage pregnancy and further cautioned that a good number of them lack adequate knowledge of comprehensive sexuality education [13], thus posing a major question about the effectiveness of their sexual and reproductive health empowerment.

Study Objective

This study aimed to describe pathways to SRHE among Adolescent Girls in a resource-constrained setting in Cameroon's Southwest

Region, which has been affected by a socio-political crisis since 2016.

Materials and Methods

Research Design

This study employed a survey design, specifically a concurrent triangulation mixed-methods approach that integrated quantitative and qualitative methods to collect data from different stakeholders in the initial phase. This approach collected quantitative and qualitative data concurrently to strengthen the validity and credibility of the findings through triangulation. The second phase used a sequential exploratory mixed-methods approach, in which trends and findings from the initial phase informed the development of an interview guide to explore identified strengths and weaknesses and capture key informants' general perceptions of the subject matter. The quantitative component focused essentially on adolescent girls. For the qualitative component, the study targeted parents, educators, health personnel, and key informants because they were involved not only in implementing policies but also in conceiving and developing them.

Study Area and Setting

The study was conducted in the Tiko Health District, located in the Fako Division of the Southwest Region of Cameroon. The district comprises nine health areas and approximately 94 communities, with an estimated population of 104,224 following the 2021 population census [14]. The district delivers health services through a decentralized system involving district health authorities, health facilities, and community-based health workers (CHWs) who implement CDI (Community-Directed Interventions). Since 2016, the region has experienced a socio-political crisis that poses enormous challenges to implementing frontline health programs and has significantly contracted the economy [15]. Disruption and insecurity have also affected the financial sector, and violence and the collapse of economic activity have reduced employment [15].

Study Population and Sampling

The study population included adolescents, household heads, educators, health personnel, and policymakers from various sectors. Adolescent girls were central to the study. Still, the individual determinants of their sexual and reproductive life are highly influenced by various socio-political and cultural factors included in the study, which contribute to shaping their psychological and socio-economic development. For the quantitative component, we determined a minimum sample size of 410 adolescent girls using the single-population proportion formula, assuming a 95% confidence level, a 5% margin of error, and a 50% prevalence to estimate the optimal sample size. For the qualitative component, we purposively and conveniently sampled 10 educators, 24–32 parents, 10 health personnel, and 15 key informants from the diversified sectors described earlier. We selected health areas and communities through simple random sampling to ensure geographical representation across the district. We conveniently sampled adolescent girls in the communities and, because parental consent was required, sampled those under 16 years at home. For the qualitative study, participants were purposively and conveniently sampled.

Data Collection Tools and Procedures

Researchers used a semi-structured questionnaire to collect information from active adolescent girls through face-to-face interviews, after administering the assent form to those aged 16 years and above and the consent form to the parents of those under 16 years. The information included the demographic characteristics, the home environment (socio-economic status, parenting style, support, norms, physical, lifestyle), physical environment and lifestyle, school environment, community and socio-cultural

norms, health system (accessibility, youth-friendly services, provider attitudes), legal and policy environment (rights, protection frameworks), conflict and fragility context (Southwest Cameroon crisis), individual mediators, and empowerment dimensions as predictors of sexual and reproductive empowerment, which, on its own, was appraised under the section labeled SRH empowerment outcomes. This last section was adapted from the SRH scale. The last section consisted of pregnancy and contraceptives, which is structured in the form of open-ended questions to capture adolescent girls' perceptions of the risks of unsafe sexual life and their suggestions to reduce them,

Validity of Data Collection Instruments

The study ensured the validity of the data collection instruments through content, construct, and face validity procedures. A public health research supervisor and a statistician reviewed the instruments to assess clarity, relevance, and alignment with the study objectives. We conducted a pilot study in Molyko and Mile 16 health areas in Buea Health District, which were not included in the final sample, to test comprehensibility, feasibility, and contextual appropriateness. Feedback from the pilot study informed refinements to the instruments' wording, response categories, and data-collection procedures.

Reliability of Data Collection Instruments

We assessed the quantitative instrument's internal consistency using Cronbach's alpha coefficient. The reliability coefficients ranged from 0.777 to 0.963, indicating very good to excellent internal consistency for adolescent girls. For qualitative tools, expert review using the parallel method and pilot testing improved reliability by ensuring clear, consistent interpretation of questions. We standardized and cross-checked data-collection procedures to minimize measurement error.

Ethical Considerations

The Ethics Committee of the Regional Delegation of Public Health for the Southwest Region granted ethical approval, and the Regional Delegation of Public Health granted administrative authorization, with support from Texila American University, Guyana. Participants were informed about the study's purpose and procedures before data collection. Participation was voluntary, and respondents could decline or withdraw at any time without negative consequences. The researchers obtained informed consent from all participants before interviews and questionnaire administration. The researchers maintained confidentiality and anonymity by not recording personal identifiers; they backed up all collected information, used it strictly for research purposes, and reported it in summary form.

Data Analysis

The team collected adolescent girls' survey data electronically using tablets running the Kobo Collect platform. The electronic tools included skip patterns, validation rules, and range checks to reduce entry errors. The team uploaded completed questionnaires daily to a secure, password-protected server and backed them up regularly. The field supervisor and statistician reviewed submitted forms each day to identify missing data or inconsistencies and ensure data quality. The team audio-recorded key informant interviews with participants' assent, transcribed them verbatim, and translated them into English where necessary. The research team stored all transcripts and field notes in encrypted folders accessible only to the team. The team analyzed quantitative data using IBM SPSS Statistics version 27. We used descriptive statistics, including frequencies, percentages, means, and standard deviations, to summarize adolescent girls'

perceptions. Multiple-response analysis was conducted where applicable. We identified critical predictors of empowerment using Binary and Multinomial Logistic Regression, preceded by bivariate analysis with the Chi-square test to identify significant associations with the dependent variable. We abstracted qualitative data through thematic analysis using ATLAS.ti and NVivo. We generated codes from the transcripts and grouped them into broader themes, compiling illustrative quotations and grounded summaries into code-grounding-quotation tables following the positivism paradigm to complement the quantitative findings and support interpretation.

Results

Socio-Demographic Characteristics

A total of 445 participants took part in the study, including 384 adolescent girls, 11 educators, 24 parents, 15 health personnel, and 11 key informants. The return rate was below 100% for adolescent girls and key informants. For adolescent girls, the return rate was 93.7%, and working in remote areas during this socio-political crisis contributed to this. For key informants, the return rate was 73.3%, with some feeling embarrassed about addressing policy issues related to adolescent SRHE; the remaining 100% or more, with an overall return rate of 94.9%. Adolescent girls and stakeholders were well stratified by demographic characteristics, which supported the representativeness and validity of the data (Tables 1 and 2).

Table1. Socio-demographic Characteristics of Adolescent Girls

Variable	**Category**	**Adolescents (N=384)**	
		Frequency	**Percent**
Type of locality	Urban	313	81.5
	Rural	71	18.5
Age	10–15	191	49.7
	16–19	193	50.3
Age of primary partner	15–19	61	15.9
	20–29	121	31.5
	30–35	8	2.1
	Not yet	194	50.5
Source of financial support	Self	78	20.3
	Parent/guardian	213	55.5
	Romantic partner	93	24.2
Employment status	No employment	281	73.2
	Formal sector employment	32	8.3
	Informal sector employment	71	18.5
Age at sexual debut	12–15	39	10.2
	16–19	130	33.8
	Not yet	215	56.0
Number of children	0	279	72.7
	1	91	23.7
	2	14	3.6
Marital status	Married	37	9.6
	Single	293	76.3

	Engaged	54	14.1
Religion	Traditional religions	16	4.2
	Christianity	317	82.5
	Islam	30	7.8
	Do not believe	21	5.5
Person primarily in charge of sexual and reproductive education of the girl child in the family	Father	66	17.2
	Mother	147	38.3
	Both	171	44.5
Parents are alive	Dead	67	17.4
	Alive	317	82.6
Person with whom currently living	Father and mother	152	39.6
	My father	29	7.6
	My mother	45	11.7
	My uncle/aunt/other relative	22	5.7
	Family friend	14	3.6
	Alone	122	31.8
Principal occupation of parents/guardian	Unskilled / semi-skilled worker	284	74.0
	Skilled worker	100	26.0
Highest level of school attained by parent/guardian	Never been to school through primary	76	19.8
	Secondary and high school	127	33.1
	Post-secondary and university	181	47.1
Perceived status of family	Poor	55	14.3
	Average	294	76.6
	Rich	35	9.1

Table 2. Socio-demographic Characteristics of Stakeholders

Variable	**Category**	**Parents n (%)**	**Educator n (%)**	**Health personnel n (%)**	**Key informants**
Sex	Male	50.0 (12)	54.6% (6)	26.7% (4)	54.5% (6)
	Female	50.0 (12)	45.4% (5)	73.3% (11)	45.4% (5)
Age group	16–24 years	16.7% (4)	27.3% (3)	40.0% (6)	0.0% (0)
	25–54 years	83.3% (20)	54.5% (6)	60% (9)	90.9% (10)
	55–64 years	0.0% (0)	18.2% (2)	0.0% (0)	9.1% (1)
	≥65 years	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Level of education	None	4.2% (1)	0.0% (0)	0.0% (0)	0.0% (0)
	Primary	20.8% (5)	0.0% (0)	0.0% (0)	0.0% (0)
	Secondary	33.3% (8)	0.0% (0)	0.0% (0)	9.1% (1)
	Tertiary/University	41.7% (10)	100% (11)	100% (11)	90.9% (10)

Actions Toward Fostering the SRHE of Adolescent Girls

Table 3: Things Parents Discuss with their Girl Child when Educating them on Sexual and Reproductive Life

Code	Code description	Grounding	Quotation
Reporting	Reporting to parents or any indicated person when faced with unfriendly persons or attitudes, or any form of abuse	41.7% (10)	"That if there is someone who is talking all those types of things to her, she should come and tell me, that she should not hide from me, because I don't want her to bring me disgrace back home." (Rural female parent); "How to keep themselves safe and also teach them how to identify someone that can abuse them and also report back" (Urban female parent); "Another topic parents can talk to their daughters is how to handle boys in class because at that stage there are males that in class, will approach them in different ways, so the parents have to tell them that when they do so they can report to the teachers or they can report home, so that the situation can be handled" (Urban female parent).
Unsafe social environment	Unsafe and risky social environment, unwanted pregnancy, risk of rape and other sexual abuses, abortion and associated risk, as well as STIs	37.5% (9)	"I tell her everything that I have passed through, let her know that the outside is not fine" (Rural female parent); "she is not supposed to interact anyhow, for instance meeting men in closed places alone because they can easily take advantage of her or they can rape her, stuffs like that" (Urban female parent); "Should not go closer to the boys because they can rape her; those are some of the advice" (Urban female parent); "Some of them even get pregnant then attempt to abort and in the process of aborting they die" (Urban female parent); "she should be very careful with boys because she can get pregnant at any time" (Urban female parent).
Menstruation	Menstruation and menstrual hygiene, calculating on menstrual cycle	33.3% (8)	"I also tell her that if at all she starts seeing the blood coming out from her body, she should not shy away; she should run to any close person, she should run to me and tell me. That is what I always tell them. I also prepare them on how to use pads to protect themselves during menses and how to clean themselves" (Rural female parent); "Some sensitive topics to talk about sexual education to a girl child are how to calculate her menstrual cycle, so she should be able to calculate her menstrual cycle, so she can be safe, clean, and secure" (Urban female parent); "Menstrual cycle, how it works, to prevent pregnancy and caution her, to prevent illnesses" (Urban male parent).

Unwanted pregnancy	Avoiding unwanted pregnancy, risks and consequences of unwanted pregnancy like school dropout, jeopardized marriage	20.8% (5)	"So, at that time, if any person comes closer to you, you should stay away because if you move in you can get pregnant" (Rural female parent); "I tell her that at that age of 12, some blood starts coming out from the body of the woman and you can get pregnant" (Rural female parent); "she should be very careful with boys because she can get pregnant at any time" (Urban female parent); "I always tell her that she can get pregnant and her education will stop, that HIV has no cure" (Rural male parent); "Menstrual cycle, how it works, to prevent pregnancy and caution her, to prevent illnesses" (Urban male parent).
Self-control	Self-control, avoiding men, abstinence, risk of premature sex	20.8% (5)	"I used to advise my child; I tell her that now she is already a woman, that she should be very careful the way she meddles with men, that she should be very careful because if she goes and tries, for instance, these things that boys use to give girls, that she should not take and that she should not hide things from me" (Urban female parent); "I always tell them not to take money from strangers, that if they lack anything they should tell me" (Rural male parent).
STIs	Risk of sexually transmitted infection	20.8% (5)	"I always tell her that HIV has no cure" (Male rural parent); "Also, I will tell her about the consequences of sex, for instance, you can become pregnant, you can have STDs" (Urban male parent).
Partner choice	Ability to choose a partner with moral aptitude	20.8% (5)	"As for the big ones, I don't even teach them again how they should use pads, and so on, because all of them are going to school; they have already learned those things in school. So, the only thing I tell them now is that they should know the type of man or boyfriend they should follow, that they should not follow the type that will get them pregnant. I am already aware of the fact that I cannot prevent them from meddling with boys; I only guide them on how they can meddle with them safely." (Rural female parent)
Self-protection	The child should know boundaries to be able to self-protect her sexual organs	16.7% (4)	"As for me, I have girls that are still small and some that are already matured. For those small ones, I tell them that if any man touches their breast or their private parts ("lass"), report to me. I also tell them that there are some types of play like daddy and mummy ("Papa and mamy"); I always tell them to avoid that types of play because it is during that types of play that they trigger them to do certain types of things that they see in films or that their

			mothers are doing" (Rural female parent); "I also caution them that in case a man touches them at a sensitive place, because I have already told them about their private parts, let them come and tell me" (Rural female parent); "That if any person asks her for a number or to sleep with her, she should report home" (Rural male parent); "My girl is 11 years old. When she was 4, I told her that nobody should touch her vagina. One day she reported to me that her madame touched it when she went to urinate" (Rural male parent);
Proactive safety	Proactive safety measures ensuring the safety of the child so that she is not a victim of sexual predators, early pregnancy, STIs, sexual abuse, or rape	16.7% (4)	"I tell her of those things such that she should be ahead, so that if she finds herself in those things she should be responsible for the consequences, so I always tell her about the consequences so that she should not find herself in it" (Urban male parent); "To prevent illnesses" (Urban male parent).
Premature sex / Premarital sex / Abstinence	Caution children on the risk of premature sex, the need for abstinence	12.5% (3)	"I first of all make them understand that they are still tender children, and that they have nothing to do with sex as of now until when they will reach the year of 22" (Rural female parent); "Things that I tell my girl child are that she should get married before having sex because if you are having sex before marriage, even if you are too protective, one day you will fall into a trap where you become pregnant. I also tell her that if you want to fall into those temptations, you should use protection" (Urban male parent).
Body change / Puberty	Signs of puberty as reflected on the body and associated risks	12.5% (3)	"About sex education, the first thing I like to discuss is the changes that take place in their skin, what makes them different from men, yeah, that is talking about the female organ, the difference with male, the development, what they have to understand, the stage-by-stage development that will take place in their body" (Urban female parent); "Ok I can talk about the changes that can occur on her body as she is growing, for instance breast can start growing from the chest while this cannot happen with boys and then after sometime she will start menstruating so I have to explain to her that when this time arrives and your breast also start showing you should not be afraid because that is what happens normally to women and when the time you start seeing blood

			comes , you should not be afraid, come and tell me so that I will tell you how to go about it; so all those things I have to make her know that there will be a time that her body will change completely and by then she would have grown from a girl to a woman" (Urban female parent); "Some of the topics that I discussed with my girl child about sex education are her secondary sexual development, the secondary sexual development that happens to her body like enlarged breasts, pubic hairs, menstruation, and she has to know that when she sees all these developments in her body then she has grown into a woman" (Urban female parent).
Caring of reproductive organs	How to care for the reproductive organs	8.3% (2)	"Teaching also how to care for those special body parts that are different from what males have" (Urban female parent); "she has to take proper hygiene, proper care of herself" (Urban female parent).
Safe sex	The right age to engage in sex, and how to go about safe sex	8.3% (2)	"Also talk to them about the proper sexual intercourse itself; they have to know the right age at which they can engage, and how to keep themselves safe" (Urban female parent).
Identifying predators	Enhancing ability to identify sexual predators and reporting	8.3% (2)	"Teach them how to identify someone that can abuse them and also report back" (Urban female parent).
Peer influence	Risk of peer influence as one can be misled by bad girls with whom one socializes	8.3% (2)	"For me the things you should discuss with her are the people you associate yourself with because when you associate with some girls nowadays they are going to lead you in some places where you cannot come out from there or and also when body starts changing, you tell her about her life" (Urban male parent); "I will tell her about the type of friends she should be with either a boy or girl, that she should watch over the type of friend that she will be with because if she has a bad friend even though she is a good child the friend can also lead her into bad things and finally she will find herself into a situation that she will not like" (Urban male parent).
Not started / Tender children	Children at 3 years old perceived too tender to be introduced to topics on sexual life	4.2% (1)	"My children are still tender, so I have not yet started talking with them, though I am prepared to do so from the age of 10 years, as I earlier said" (Rural female parent).

Focus on younger ones	Focus on younger ones perceived as more receptive	4.2% (1)	"I talk with them; there are some that, as you caution them, bang they adjust, but there are some that envy ("langer"), as my sister just said; I agree with her. I focus on the younger ones" (Rural female parents). "I tell elder ones things concerning men or boys, but when I told them they were not taking word from me and when they fell victim, I told them that now let them bear the consequences" (Rural female parent).

Things parents discuss with their girl children when educating them on sexual and reproduction life ranged from reporting to parents or any indicated person when faced with unfriendly persons or attitudes; unsafe and risky social environment, unwanted pregnancy, risk of rape, and other sexual abuses, abortion and associated risks, STIs; menstruation and menstrual hygiene, calculating menstrual cycle; avoiding unwanted pregnancy and early pregnancy, risks and consequences of unwanted pregnancy like school dropout, jeopardized marriage; self-control, avoiding men, abstinence, risk of premature sex; risk of sexually transmitted infections; the child knowing boundaries to be able to self-protect her sexual organs; proactive safety measures ensuring the safety of the child for her not to be victim of sexual predators; sexual abuses or rape; choice of partner with moral aptitude; signs of puberty as reflected on the body and associated risks; how to care for the reproductive organs; the right age to engage in sex, and how to go about safe sex; enhancing ability to identify sexual predators and reporting; and risk of peer influence as one can be misled by bad friends with whom one socialized (Table 3).

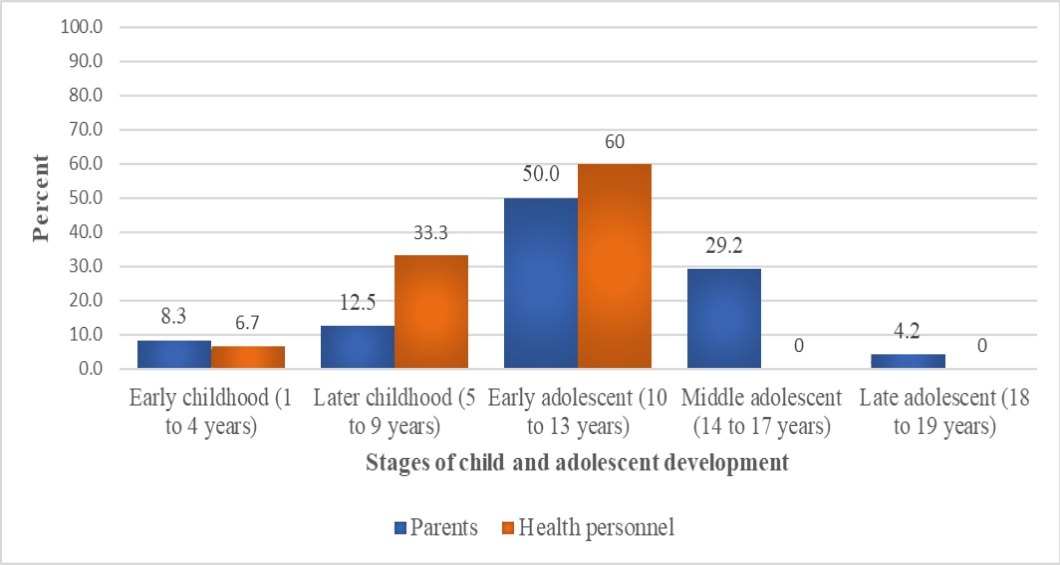


Figure 1. Stages of Child and Adolescent Development at Which Parents and Health Personnel Start Educating Girls on their Sexual and Reproductive Life

Parents and health personnel mostly started educating girls on their sexual and reproductive life during their early adolescence, that is, between 10 and 13 years, and cumulatively from 5 to 13 years old (Figure 1), with reasons or actions taken stratified to the stages of growth (Table 4). Stakeholders generally focused on this group, perceived as more receptive, while some perceived younger ones as too tender to be introduced to topics on sexual life, notably in early childhood.

https://doi.org/10.21522/TIJAR.2014.13.04.Art025

Table 4. Actions and Reasons for Starting to Educate Adolescent Girls at a Particular Developmental Stage

Development Stages	**Reasons**
Early childhood (1 to 4 years)	Self-protection, as the child should know boundaries to be able to self-protect her sexual organs
	Proactive safety; to proactively ensure the safety of the child so that she is not a victim of sexual predators, early pregnancy, STIs, sexual abuse, or rape.
	School experience with other children who confide their experiences.
Later childhood (5 to 9 years)	Early sensitization; reasoning age; onset of puberty; and active / and interactive with the environment.
	Reasoning age; the age when the adolescent is endowed with the capacity to reason, think coherently, and use logic.
	Unsafe social environment; the social environment predisposes to sexual promiscuity, thus putting young girls at risk.
	Proactive safety; to proactively ensure the safety of the child so she is not a victim of sexual predators, early pregnancy, STIs, sexual abuse, or rape. Perceived importance of early or proactive sensitization before the adolescent indulges in an active sexual life.
Early adolescent (10 to 13 years)	Puberty/sexual maturity; enhancing self-control; knowing right for self-protection; and childbearing age.
	Proactive safety; to proactively ensure the safety of the child so that she is not a victim of sexual predators, early pregnancy, STIs, sexual abuse, or rape. Perceived importance of early or proactive sensitization before the adolescent indulges in an active sexual life.
	Girls are perceived to be sexually emancipated early nowadays, having a boy partner earlier.
	Curiosity/exposure: at this age, the child is already curious, exploring, and exposed to the outside world, movies, schools, etc.
	Reasoning age: the age at which the adolescent develops the capacity to reason coherently and logically.
	To enhance free and friendly communication between parent and child.
	Risk of unwanted pregnancy.
	Sexual maturity, as the girl has attained puberty and can be sexually active.
	Risk of STIs.
	Unsafe social environment; the social environment is predisposing to sexual promiscuity, thus putting young girls at risk. Evidence of negative role models, like girls with unwanted pregnancies.
	Poor sex differentiation in school as boys and girls are freely mixed up.

	Self-protection; the child should know boundaries to be able to self-protect her sexual organs.
Middle adolescence (14 to 17 years)	Mother's early intervention at tender ages.
	To avoid failure in life and unsuccessful outcomes.
	Risk of unwanted pregnancy.
	Sexual maturity, as the girl has attained puberty and can be sexually active.
	Risks of STIs.
	Trigger signs as the child is growing.
	Unsafe social environment; the social environment predisposes to sexual promiscuity, thus putting young girls at risk. Evidence of negative role models, like girls with unwanted pregnancies.
	Proactive safety; to proactively ensure the safety of the child so she is not a victim of sexual predators, early pregnancy, STIs, sexual abuse, or rape.
Late adolescent (18 to 19 years)	Unsafe school environment / Peer influence; the school environment is predisposing to sexual promiscuity, thus putting young girls at risk, notably peer influence in secondary school.

SRH Empowerment

SRH empowerment thus did not emerge as a major problem in this study context. However, the impact was questionable, as though empowered, adolescent girls still indulged in sex relatively early, besides unwanted/early pregnancy and low interest in contraceptive methods (Figure 2).

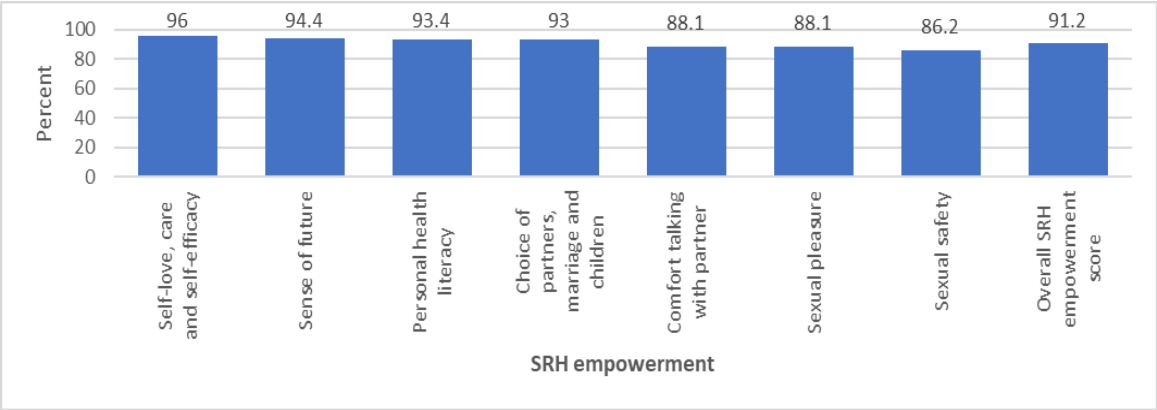


Figure 2. SRH Empowerment of Adolescent Girls

Classification of Empowerment Facilitators

Adolescent girls highlighted neighborhood standards or conditions as the most ineffective facilitator of their SRH empowerment, followed by community and social norms, conflict and fragile context, and the health system, with a level of ineffectiveness of 10% or above. This high discrepancy thus highlights the unstructured nature of the SRH empowerment mechanism (Figure 3).

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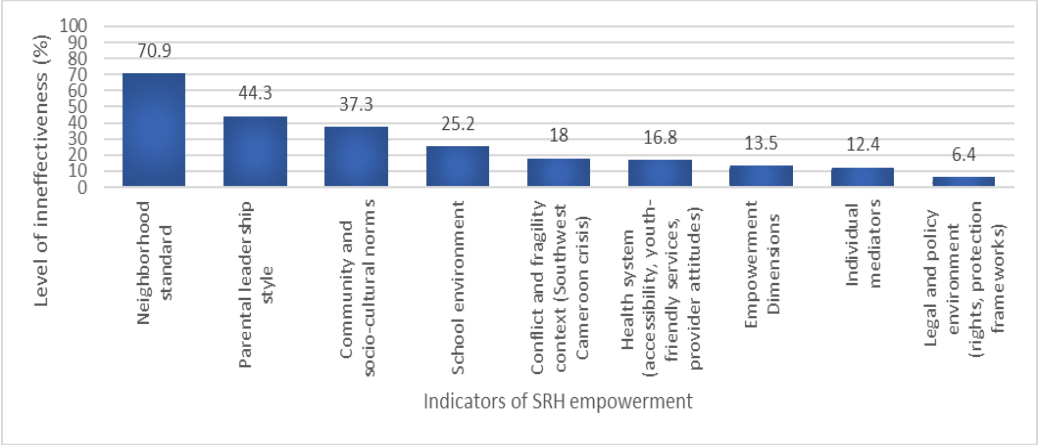


Figure 3. Ineffectiveness of Indicators of SRH Empowerment of Adolescent Girls

Neighborhood standard was the most ineffective in enhancing adolescent girls' SRHE, with a perceived ineffectiveness proportion of 70.9%. It was followed in this perspective by parental leadership style, community and socio-cultural norms, school environment, conflict and fragility context (Southwest Cameroon crisis), health system (accessibility, youth-friendly services, provider attitudes), empowerment dimensions, and individual mediators, with legal and policy environment (rights, protection frameworks) being the least concern.

Contraceptives

Adolescent girls generally have heard of contraceptive methods to prevent or control pregnancy and childbearing, 81.8% (314). The most highlighted contraceptive method used was the condom (Figure 4).

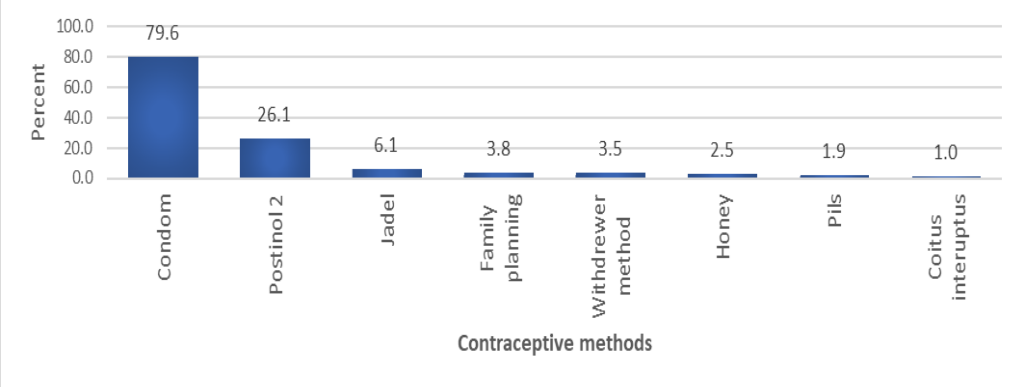


Figure 4. Adolescent Girls' Description of Contraceptive Methods Used

Willingness to Use Contraceptive Methods

Though adolescent girls generally said they were aware of and had access to both forms of contraceptive methods, their willingness to use them was relatively low, at 49.7%. For the most highlighted contraceptive methods, notably condom, pill, Jadelle, family planning, withdrawal method, and pills, the percentages of adolescent girls who were comfortable using them were 52.9%, 54.3%, 55.6%, 57.1%, 55.6%, and 42.9%, respectively.

Teenage Pregnancy

Cumulatively, 27.3% (105) had at least one child (Table 5). The number of children was significantly dependent (P = 0.000) on adolescents' age, whereby the younger ones (10-15 years) mostly did not have children, with a proportion of 87.4% (167), as against 58.0% (112) for the older ones (16–19 years).

Table 5. Association Between Adolescents' Age and Number of Children

Age	Stats	Number of Children			Total
		0	1	2	
10-15	n	167	24	0	191
	%	87.4%	12.6%	0.0%	100.0%
16-19	n	112	67	14	193
	%	58.0%	34.7%	7.3%	100.0%
Total	n	279	91	14	384
	%	72.7%	23.7%	3.6%	100.0%

χ2-test: χ2 = 45.152; df=2; P = 0.000.

Age at Sexual Debut

In fact, most of the adolescent girls had already had sex, and among them 23.1% had it relatively young, between 12 and 15 years (Table 6). This indicator (age of sexual debut) was then used in predictive modeling to identify significant and critical predictors of risky sexual behavior as a corollary of the unstructured SRH empowerment mechanism depicted by this study.

Table 6. Description of Age of Sexual Debut

		Frequency	Percent	Valid Percent
Valid	12–15	39	10.2	23.1
	16–19	130	33.9	76.9
	Total	169	44.0	100.0
Missing	Not yet	215	56.0	
Total		384	100.0	

Table 7. Bivariate Association with Age of Sexual Debut as Dependent Variable

Predictors	Chi-Square test			Comment
	Score	df	Sig.	
Health area	0.192	1	0.662	There was basically no discrepancy among the health areas
Age of primary partner	27.845	1	0.000	The age of the primary partner increased significantly with the adolescent girl's age.
Source of financial support	5.921	1	0.015	Those who depended on a parent/guardian engaged in sex earlier (12-15 years) than those who depended on themself or a romantic partner. Statistics also revealed that younger adolescents depended more on a parent/guardian than older adolescents. So, this relationship was more likely not to be significant after controlling for adolescent age.
Employment status	26.020	1	0.000	Those with no employment significantly engaged in sex earlier.
Religion	2.718	1	0.099	The independent variable was highly skewed. Above all, the dependence was not statistically significant, though Muslims had the highest proportion, followed

				by Christian with no traditionalists engaging in sex earlier.
Who is primarily in charge of Sexual and reproductive education of the girl child in the family	0.715	1	0.398	Though in the context where both parents engaged in SRH education, adolescent girls were least engaged in sex earlier, the discrepancy with father or mother was not obvious.
Parent's marital status	0.215	1	0.643	Though in the context where parents were separated or cohabiting, adolescent girls engaged in sex earlier; this discrepancy was statistically significant.
Parents are alive	4.999	1	0.025	Adolescent girls with parents dead significantly engaged in sex earlier.
Person with whom currently living	14.122	1	0.000	Those living only with mother or a family friend significantly engaged in sex earlier.
Highest level of school attained by either parent/guardian	4.256	1	0.039	Those with a parent who has never been to school significantly engaged in sex earlier.
Highest standard principal occupation of either parent/guardian	4.728	1	0.030	Adolescent girls of parents with unskilled / semi-skilled work significantly engaged in sex earlier.
Highest standard category of work of either parent	2.341	1	0.126	Though adolescent girls of self-employed parents engaged in sex earlier than those of parents under paid employment, this discrepancy was not statistically significant.
Type of locality	0.577	1	0.448	Adolescent girls in urban areas engaged in sex earlier than those in rural areas, but this dependence was not statistically significant.
Category of neighborhood	8.362	1	0.004	Adolescent girls in low-status neighborhoods significantly engaged in sex earlier.
Parental leadership style categorized	3.148	1	0.076	Although parental leadership style was perceived as inadequate, adolescent girls engaged in sex earlier, the difference was not statistically significant. Permissive and tolerant approaches characterized inadequate parenting leadership.
Neighborhood standard categorized	9.685	1	0.002	Where neighborhood standard was low with poor hygiene and sanitation, promiscuity, noise, etc., adolescent girls were significantly more exposed to early sex.
Community and socio-cultural norms	0.015	1	0.902	There was basically no association here.
Health system (accessibility, youth-friendly services, provider attitudes)	0.635	1	0.426	Although adolescent girls perceived it to be inadequate, they engaged earlier in sex; the discrepancy was not statistically significant.

Legal and policy environment (rights, protection frameworks)	3.598	1	0.047	Where it was perceived as inadequate, adolescent girls engaged in sex earlier.
Conflict and fragility context (Southwest Cameroon crisis)	6.257	1	0.012	Where the socio-political crisis was perceived as a problem, adolescent girls engaged in sex earlier.
Individual mediators	1.384	1	0.239	Where it was perceived as inadequate, adolescent girls engaged in sex earlier, though this discrepancy was not statistically significant.
Empowerment dimension	6.761	1	0.009	Where it was perceived as inadequate, adolescent girls engaged in sex earlier, and this discrepancy was statistically significant.

Age of primary partner, source of financial support, employment status, parents are alive, person with whom currently living, highest level of school attained by either parent/guardian, highest standard principal occupation of either parent/guardian, category of neighborhood, neighborhood standard, legal and policy environment (rights, protection frameworks), conflict and fragility context (Southwest Cameroon crisis), and empowerment dimension were significantly associated with age at sexual debut ($P < 0.05$) as presented in Table 7. We then integrated these predictors into a multivariate analysis to characterize their predictive effects while controlling for one another.

Table 8. Binary Logistic Regression Depicting Significant and Critical Predictors of Age at Sexual Debut Alongside their Odds Ratios

Predictors	**B**	**S.E.**	**Wald**	**df**	**Sig.**	**Exp(B)**	**95% C.I.for EXP(B)**	
							Lower	**Upper**
Age of primary partner	0.302	0.535	0.318	1	0.573	1.352	0.474	3.862
Source of financial support	0.047	0.457	0.011	1	0.918	1.048	0.428	2.566
Employment status	2.223	0.668	11.072	1	0.001	9.238	2.494	34.220
Parental leadership style	2.466	0.818	9.081	1	0.003	11.777	2.368	58.566
Person with whom currently living	0.414	0.158	6.880	1	0.009	1.513	1.110	2.062
Highest level of school attained by either parent/guardian	−0.026	0.376	0.005	1	0.945	0.974	0.466	2.036
Principal occupation of either parent/guardian	0.979	0.779	1.580	1	0.209	2.662	0.578	12.253
Category of neighborhood	0.494	0.547	0.816	1	0.366	1.639	0.561	4.788
Neighborhood standard	1.088	0.640	2.889	1	0.089	2.967	0.847	10.400
Legal and policy environment (rights, protection frameworks)	0.817	1.478	0.306	1	0.580	2.263	0.125	40.992

Conflict and fragility context (Southwest Cameroon crisis)	1.744	0.768	5.158	1	0.023	5.718	1.270	25.743
Empowerment dimension	0.392	0.950	0.170	1	0.680	1.479	0.230	9.515

Four critical (P < 0.05; OR > 1; LB-OR > 1) predictors of age at sexual debut emerged from the set, notably employment status, parental leadership style, person with whom currently living, and conflict and fragility context (Southwest Cameroon crisis). Bivariate association earlier revealed that those with no employment significantly engaged in sex earlier, the same with those who had dead parents, those living only with a mother or a family friend, and that where the socio-political crisis was perceived as a problem, adolescent girls indulged in sex earlier (Table 8 & 9).

Table 9. Multinomial Logistic Regression Depicting Significant and Critical Predictors and Categories' Odds Ratios of Age at Sexual Debut

Predictors (Predicting against 12-15 years, thus reference category 16-19 years)		**Sig.**	**Exp(B)**	**95% Confidence Interval for Exp(B)**		**Evidence**	**Quotations**
				Lower Bound	**Upper Bound**		
Employment status of parent/guardian	No employment	0.006	96.088	3.635	2539.975	Quantitative / Qualitative	"Some are encouraged by the parents to bring money home" (Secondary school educator); "Poverty" (Health personnel); "Family is poor" (Female health care manager)
	Formal sector employment	0.206	8.214	0.314	214.565		
	Informal sector employment	.	.	.	.		
Parental leadership style	Inadequate	0.010	11.321	1.775	72.199	Quantitative / Qualitative	"Parents not talking to their children" (Rural female parent); "Most parents are avoiding discussing this issue with their children. This should be addressed." (Rural male parent); "Parents should advise their children"
	Adequate	.	.	.	.		

							(Secondary school educator); "As for non-comfortability, I will say 40%; the problem is really lack of knowledge because if you have not received sex education to train your girl, they will not have enough information to give them" (Female social affairs counselor)
Person with whom living	Father and mother	0.013	11.584	1.670	80.339	Quantitative	"Dead parents, I have had a situation where the boy in question and the girl, their parents are all dead" (Female social affairs counselor)
	Father	0.245	3.414	0.431	27.014		
	Mother	0.033	9.812	1.197	80.402		
	Other family member or relative	0.310	4.287	0.258	71.263		
	Friend	0.266	9.286	0.184	469.345		
	Alone	.	.	.	.		
Conflict and fragility context (Southwest Cameroon crisis)	Inadequate	0.028	5.892	1.214	28.601	Quantitative / Qualitative	"The crisis has also caused disorder, promiscuity" (Urban male parent); "Yes, because she meets with people from different areas and with different behaviors, attitudes" (Urban male parent); "Many girls have become pregnant" (Health personnel); "Some girls in conflict areas have been so traumatized that
	Adequate	.	.	.	.		

							they don't feel comfortable talking to people because of their experiences in the past" (Health personnel); "Some who have been assaulted find it difficult" (Health personnel); "Plunged them to hardship" (Female health care manager)

Qualitative data unfolded other barriers, and these were scrutinized in terms of communication, cultural (beliefs and taboos), equipment / logistic, societal (beliefs, taboos, behavior, lifestyle, or attitude of people in the community), psychological / acceptance from the girl, and legal and crisis contexts (Table 9).

Barriers and Response Measures

Table 10. Stakeholders' Descriptions of Barriers they Encounter When Educating the Adolescent Girl on her Sexual and Reproductive Life and How they overcome Them

Code	Code description	Quotation	Stakeholder concerned
Communication			
From adolescents			
Shyness	Shyness is a feeling of fear and embarrassment.	"The students are always shy and uncomfortable" (Secondary school educator); "Most of them are shy about discussing their sexual health with others" (Health personnel); "For me, when I started talking with her, she was shy; when I was talking about menses, she was shy, but she has started getting used to now" (Rural female parent).	Educators, health personnel, parents
Language barrier	Language barriers, such as some people not being literate in official languages or not being familiar with medical terminology.	"Language barriers" (Health personnel); "Difficulties to understand medical terminologies" (Health personnel).	Health personnel
Distance	Distance when one faces remote areas.	"Distance" (Health personnel).	Health personnel

Confidentiality	Confidentiality, as an adolescent fears disclosure.	"Confidentiality" (Health personnel).	Health personnel
Surprisingness	Surprisingness, as they find such talk or topic extraordinary and least expected in their present context.	"They sometimes feel shy, and some look surprised" (Secondary school educator).	Educators
Lying	Telling lies, things that are not true or based on facts.	"At times they tell lies" (Secondary school educator).	Educators
Aggressiveness	Aggressiveness, as some are hostile, bold, or manifest violent reactions.	"Some are aggressive at times" (Secondary school educator)	Educators
Disrespect / Indifference	Girls despise their parents, showing contempt or scorn, indifference, and not having time for them.	"My own children, as we are discussing, they will put their heads down as if it is not even what they know [Animator: They are shy]: Yes. They act as if it is not even what they do. You will argue a point till the end, but they will only laugh. You will talk some point, and surprisingly they will shout 'eh antyyyy' as if what you are talking about does not even exist" (Rural female parent); "My own child, when I am talking with her, she will instead cover her eyes, making as if she is not hearing" (Rural female parent).	parents
Misinterpretation	Misinterpretation by taking parents' words as lies.	"As for me, when I talk with my children, it is as if I am instead lying, whereas there are the very things that I passed through" (Rural female parent).	Parents
From educator			
Challenging introduction	Challenging to introduce the topic or start a conversation about it.	"Difficulties in starting conversation" (Secondary school educator).	Educators
Cultural (belief and taboo)			
Preference to boys	Neglect of the girl child; preference for the male.	"Neglect of girl and child given preference over the male child" (Primary school educator).	Educators
Taboo	Taboo, which is a prejudice that prohibits the use or mention of things related to sex to children or publicly.	"Some feel like taboo for such talk to underage" (Secondary school educator); "It is a taboo; they criticize the fact that they discuss to that level with children" (Secondary school educator); "Yes,	Educators, Health personnel, parents, Social affairs

		normally at the onset children are shy because it is commonly perceived that one should not hold such conversation with children" (Health personnel).	
Religious	For some religions, it is very inappropriate to talk about sex to young girls / Islam could be a barrier, as most Muslim girls don't want to open up.	"Yes, I will say there are barriers and one of the barriers I can say is religious barriers, like for example for you talking to her about sexuality, euhmm but religiously it is abnormal for you talking about sexuality to someone too young" (Urban male parent); "Most Muslim girls don't want to open up" (Secondary school educator); "For Muslim it is very inappropriate" (Health personnel).	Parents
No cultural obligation	Adolescent girls' sexual and reproductive health education is not fully integrated into local culture.	"No cultural obligation" (Secondary school educator).	Educators
Home delivery not taboo	Home delivery / traditional midwifery not taboo.	"They believe in giving birth at home" (Health personnel).	Health personnel
Male educator as taboo	Male talking to girls on sexual issues perceived as taboo.	"The belief that a man is not supposed to educate girls on reproductive issues" (Health personnel); "As a male nurse, some see it as odd" (Health personnel).	Health personnel
Equipment/logistics			
Not available	Equipment or logistics on sexual and reproductive health not provided.	"No logistics" (Secondary school educator); "None" (Primary school educator).	Educators. Health personnel
Private space	Private space for one-on-one talk not available.	"Lack teaching materials" (Health personnel).	Health personnel
Educational support tools	Lack of support educational materials	"Lack of teaching materials" (Health personnel); "Lack of equipment for good education" (Health personnel).	Health personnel
Transportation	Lack of transportation and poor road conditions during the rainy season limit outreach and coverage.	"Transportation" (Health personnel); "Need bikes" (Health personnel); "Challenge to meet them at their geographical areas" (Health personnel); "Challenge with community home visit" (Health personnel); "Limited number of outreaches" (Health personnel); "Going to such areas but in the dry season" (Health personnel).	Health personnel

Charts	Educational charts.	"Need charts" (Health personnel)	Health personnel
Economic			
No problem	No impact if the child is well brought up.	"No, this will have no impact for an educated child" (Urban male parent).	Parents
Societal (beliefs, taboo, behavior, lifestyle or attitude of people in the community)			
Stigmatization of victims of rape	Stigmatization of victims of rape who now suffer low self-esteem.	"Stigma to survivors of rape; survivors suffer low self-esteem and shame" (Primary school educator).	Educators Social affairs Health personnel
Male favoritism and impunity	Males are favored or treated with partiality, which increases the risk of exposure due to impunity.	"Males are favored and pose risk" (Primary school educator).	Educators Social affairs
Ignorance / Shyness	People are ignorant of the risks associated with inadequate sexual behaviors. Taboo, as most parents or society are shy to educate on sexuality.	"People are ignorant, and they don't accept the fact that nowadays the children are exposed to danger" (Secondary school educator); "Most parents or society are shy to educate" (Secondary school educator); "People mostly shy away from the topic" (Secondary school educator).	Educators Social affairs
Inadequate awareness	Inadequate awareness, as some communities have a backward mentality about empowering young girls.	"Some communities have a backward mentality about empowering young girls" (Health personnel); "Most are generally dismissive about counseling" (Health personnel); "People should be sensitized" (Rural male parent).	Health personnel, parents
Negative role models	Negative role models sustained in society hinder others' empowerment.	"Peer pressure" (Health personnel); "Yes, some parents don't really educate their children, and there is promiscuity around, and this can influence my child" (Urban male parent).	Health personnel, parents
Male educator as taboo	Male talking to girls on sexual issues taboo.	"The belief that a girl is not supposed to be educated on her reproductive life by a man" (Health personnel).	Health personnel
Psychological / Acceptance from the girl			
Low acceptance	Low acceptance as they shy away from the topic.	"Low acceptance" (Primary school educator); "Yes, there is acceptance but needs to be sustained" (Secondary school educator); "Others might be psychological because not everyone would like talking about sexuality. Those are some of the barriers that we can have" (Urban male parent).	Educators, health personnel, Parents/community
Low self-esteem	Low self-esteem: adolescent girls are not	"Self-efficacy" (Primary school educator).	Educators, health personnel

	happy or proud of themselves.		
Different reactions	Different reactions, as not all children comply or react the same during discussions.	"Some accept, some don't accept" (Rural female parent); "Some will accept, but some will not accept. But if she stays quiet, know that that aspect has caught her. But if you have one shouting, know that one [many articulating at the same time] she is surprised" (Rural female parent).	Parents/community Educators Social affairs
Indifference / Disrespect	Girl despising the parent, manifesting contempt or scorn, indifference, and saying they don't have time	"Some don't just have the time" (Rural female parent).	Parents/community Educators Social affairs
Health system			
Business oriented	Health system practices are said to be business-oriented, prioritizing profit over the process and outcome of care.	"Yes, because there are too many, like contraception methods, and they mostly advise girls toward that direction because they want to make money; they want to sell their drugs" (Urban male parent).	Parents/community Educators Social affairs Health personnel Legal personnel
Legal context			
None	No legal or formal context	"No legal context" (Secondary school educator); "No legal backing" (Secondary school educator) "No legal constraint" (Secondary school educator)	All
Lack of knowledge	Lack of knowledge on laws regulating sexual and reproductive education of youth or related context	"Lack knowledge of laws and rights" (Health personnel); "Not aware" (Primary school educator); "I don't know much about laws that protect SRH and the life of young girls" (Urban male parent).	All
Weak implementation of policies	Weak implementation of policies	"Weak implementation of policies" (Health personnel).	All
No consent	Some refuse to consent to participate, or their parents do	"Some give consent while others don't want to" (Health personnel).	Health personnel Legal personnel
This crisis context			
Hinder sexual education	The crisis has hindered education or other mechanisms that could enhance sexual awareness.	"This is one of the challenges that has greatly impacted negatively on sexual awareness" (Secondary school educator).	All
Facilitator of promiscuity	The crisis has facilitated social problems that hinder	"Has exposed many to social ills" (Secondary school educator); "The crisis has made young girls get into sexual	All

	sexual awareness and control of adolescent girls, thus fostering promiscuity.	activities" (Secondary school educator); "The crisis has also caused disorder, promiscuity" (Urban male parent).	
Family socio-economic challenges	The crisis has placed many families in socio-economic difficulties, thus making their girl child more vulnerable.	"Many displaced families have difficulties in accommodation, so making some of the children go astray" (Secondary school educator).	All
School drop-out	Many adolescent girls have dropped out of school because of the crisis and are therefore exposed to many sexual ills.	"Crisis causes a lot of promiscuity since the girl child stays at home without going to school and some parents don't educate their children on sex" (Secondary school educator).	All
Increase unwanted pregnancy	Increase unwanted pregnancy as many girls have become pregnant	"Many girls have become pregnant" (Health personnel).	Health personnel Parents/community Social affairs Educators
Traumatization and complete shutdown	Traumatization and shutdown, as some girls in conflict areas have been so traumatized to an extent that they don't feel comfortable talking to people because of their sad past experiences	"Some girls in conflict areas have been so traumatized that they don't feel comfortable talking to people because of their experiences in the past" (Health personnel); "Some who have been assaulted find it difficult" (Health personnel).	Health personnel Parents/community Social affairs Educators
Insecurity	Insecurity making outreach challenging	"Insecurity" (Health personnel).	All
Displacement	Challenging to handle displaced people.	"Displacement" (Health personnel); "Yes, because she meets with people from different areas and with different behaviors, attitudes" (Urban male parent).	All
Limited access to services	Limited access to services due to the crisis	"Limited access to services during crisis" (Health personnel).	Health personnel
Poverty	Poverty	"Poverty" (Health personnel).	Health personnel Parents/community Social affairs Educators

Barriers were multi-dimensional, ranging from communication and cultural factors (beliefs and taboos) to equipment/logistics, economic constraints, societal factors (beliefs, taboos, behavior, lifestyle, or attitudes of people in the community), psychological factors (acceptance by the girl), the health system, legal issues, and crisis contexts.

Regarding communication, shyness, language barriers, distance in remote areas, confidentiality, surprise, lies, aggressiveness, and despise / indifference, and misinterpretation, it was challenging for educators to introduce the topic or start a conversation about it. Preference for the boy child while neglecting the girl, taboo and religious beliefs were sources of concern. Equipment/logistics were not adequately available, as were translators. Regarding the family's economic context, it was argued that it would have no impact if the child was well brought up, though providing basic needs was advocated. Further concerns were stigmatization of victims of rape, male favoritism and impunity, ignorance/shyness, inadequate awareness, negative role models, and male educators as taboo. Regarding psychological factors and acceptance, participants pointed to low acceptance, low self-esteem, varied reactions, and indifference/despise. Regarding the health system, parents perceived it as business-oriented. The legal context was characterized by inadequate laws and regulations, limited knowledge, and weak implementation. The crisis context hindered sexual education, facilitated promiscuity, fostered family socio-economic challenges, school dropout, increased unwanted pregnancy, traumatization and closeness, insecurity, displacement with socio-economic consequences, limited access to services, and poverty (Table 10).

Table 11. Stakeholders' Perceptions of Things that Should be Done to Improve and Sustain the Sexual and Reproductive Empowerment of the Adolescent Girl

Code	Code Description	Grounding		Quotations
		n	%	
Sustained and early home-based education	Early education at home, parental involvement in sexual abuse, body safety, measures for self-defense, safe sexual and reproductive life, consistency/perseverance, and friendly communication.	52	74.3	"Talk to them early" (Rural female parent); "Yes, for me the knowledge that we give them will empower them, as they always say that knowledge is power, so the knowledge that we give them is enough to empower them" (Urban male parent); "Communicating, advising" (Urban male parent); "It has to start from their parents; the education should start from their parents" (Rural male parent)
Sustained and intensified community-based education	Sustained and intensified community-based education by providing continuous education and awareness programs on sexual and reproductive health for young girls in the community.	45	64.3	"Teachers, parents and people of good will should put heads on desk to educate children as early as possible" (Rural male parent); "We do door-to-door outreach" (Health personnel); "Community leadership and engagement" (Health personnel); "Intensify sensitization, education (Health personnel); "Proper sexual and reproductive health education, gender sexuality, respect of girl's right, laws protecting girls from abuse" (Health personnel).
Providing needs	Providing adolescent girls' needs.	39	55.7	"Provide their basic needs" (Rural female parent). "We have to make her know the

				good and the bad; we have to take care of her too, help her buy some of her things because some girls fall into temptation, they start having money from boys, and that is where they start sleeping with them" (Urban male parents).
Policy implementation	Strengthening enforcement of laws.	33	47.1	"Strengthen enforcement of laws, involve authorities and health institutions" (Health personnel).
Sustained, early and comprehensive / intensified school-based education	Early education in school, comprehensive / intensified education on sexual and reproductive empowerment, formal consideration in the curriculum.	27	38.6	"I feel like they should place more emphasis on that in schools because the lessons are very shallow; they don't really take time to educate them, to tell them how to calculate their menstrual cycle, things like that" (Urban female parent); "It should be put in the school curriculum" (Secondary school educator).
Trust, patience, friendly, accessible language, confidentiality	Build trust by making them feel safe and comfortable; be patient, friendly, and confidential; use simplified, explicit language they can understand.	21	30.0	"Make them feel safe and comfortable" (Health personnel); "Create a friendly environment" (Health personnel); "Patience" (Health personnel); "Politeness" (Health personnel); "I simplify to them using the local language for understanding" (Health personnel); "Struggle to assure about confidential matters" (Health personnel).
Mass media	Use of mass media like radio and television; this also helps to address low access to services in remote areas.	15	21.4	"Even at radio stations, even at TV stations where it can be included as a program to teach the girl child about sex education" (Urban female parent); "Media awareness" (Health personnel).
Counseling / psychological support / punitive measures	Counseling, psychological support, and assurance to increase self-esteem; punitive measures for stubborn ones.	12	17.1	"Counseling them" (Health personnel); "Reassure them that I am here to help" (Health personnel); "Girl child that don't want to take advice, those very stubborn and lazy ones should be punished; if not, they will keep misleading the younger ones" (Urban parent).
Translator	Education using translators to palliate language barriers.	8	11.4	"We educate them using translators" (Health personnel); "I look for someone they share the same tribe" (Health personnel).
Church-based education	Church-based education.	7	10.0	"Let them go for bible study; they should have a session where they train both boys and girls" (Rural female parent); "Church" (Health personnel).

Pragmatic education	Use a pragmatic approach by bringing concrete examples to change perceptions.	7	10.0	"Bringing in other people's experiences" (Rural female parent); "Educate them by narrating stories about their culture and the reality of today" (Health personnel); "Educate them with practical examples" (Health personnel).
Legal empowerment	Educate them on legal frameworks that protect girls and women.	6	8.6	"Respect of girl's rights, laws protecting girls from abuse" (Health personnel); "Respect of female rights" (Health personnel); "Laws to protect the girl child" (Health personnel).
Participatory approach	Adolescent participation in planning programs and outreach.	5	7.1	"Participation of the young girl in planning the programs for any outreach; Involving the young girls as ambassadors for any outreach" (Health personnel).
Proactiveness	Proactive self-initiative by finding materials in advance.	4	5.7	"Start sorting for products ahead of time" (Health personnel).
Educating negative role models	Extending education to children who are negative role models in the neighborhood.	3	4.3	"I just talk to the child with insistence, and when I can talk to any other child I do it" (Urban male parent); "Peer education" (Health personnel).
Punitive measures	Sanctions to be imposed on those who sexually abuse a girl or exploit them for commercial purposes.	2	2.9	"Severe sanctions should be imposed on those who sexually abuse a girl in school" (Primary school educator); "You need to condemn the practice especially for those trying to commercialize it" (Secondary school educator).
Curb laziness	Address lazy adolescent girls, as it exposes them to avoidable temptations.	2	2.9	"The lazy ones" (Rural male parent).
Family planning	Education on family planning.	2	2.9	"Family planning" (Health personnel); "For those who are sexually active, they should be educated about family planning to prevent unwanted pregnancy" (Health personnel).
Controlled social media	Social media like Facebook, Internet, WhatsApp, YouTube, TikTok, etc. should be controlled.	2	2.9	"Social media" (Rural female parent);"Social media: young girls consume a lot of adult content, which confuses their reasoning" (Secondary school educator).
Self-provision	Self-provision of education tools such as charts and videos.	2	2.9	"Making use of sexual and reproductive charts and videos" (Health personnel); "I use my phone to play practical videos for better understanding" (Health personnel).

Mood-oriented education	Mood-oriented education, that is, educating when the child is in a good mood.	1	1.4	"For me, one thing we can do is just by advising her by talking to her; do this when she is comfortable and happy, when you do something nice to her, because if she is not happy, she might not open up" (Female urban parent).
Control	Controlling the child.	1	1.4	"Communicating, advising, even controlling them; always communicating, advising" (Urban male parent).
Regular screening	Screening to adjust health issues proactively.	1	1.4	"Regular screening" (Health personnel).
Economic empowerment	Economic empowerment.	1	1.4	"Being empowered with other trade" (Health personnel).
NGO support	Support from NGOs.	1	1.4	"Support from NGOs" (Health personnel)
Early vaccination	Vaccination at a younger age to stop STDs.	1	1.4	"Vaccination at a younger age to stop STDs" (Health personnel).
Youth-friendly health services	Accessible youth-friendly health services.	1	1.4	"Accessible youth-friendly health services" (Health personnel).
Mobile health services	Mobile health services to attend to displaced people.	1	1.4	"Mobile health services" (Health personnel).

N=70

Stakeholders' perceptions of what should be done to improve and preserve the sexual and reproductive empowerment of adolescent girls included sustained, early home-based education; sustained, early, and comprehensive/intensified school-based education; sustained and intensified community-based education; and awareness and education through mass media for the major ones. Nevertheless, other suggestions should not be neglected, given the study's qualitative theoretical perspective, though it applied positivism to further reduce the abstraction of the information (Table 11).

Discussion

The study aimed to dissect the pathway to SRHE for adolescent girls, identify the inherent challenges, and propose a framework to strengthen this crucial developmental stage in a resource-constrained setting: the Southwest region of Cameroon, which has faced a socio-political crisis since 2016. Though adolescent girls generally portrayed a satisfactory level of SRH empowerment, the paradox was a high rate of early sex, early pregnancy, and low willingness to use contraceptives. Adolescent girls with no alternative source of income, for those who were of age to engage in income-generating activities, engaged in sex earlier; those with dead parents were critically exposed to early sex; the same for those living with their mother or a friend. Adolescent girls' indulgent sex cut across rural and urban areas; in the context where both parents engaged in SRH education, adolescent girls were least likely to engage in sex early, the same with married parents. Parental leadership style was not actually a hindering factor, as parents were generally not permissive when it came to paying attention to the sexual life of their adolescent girls, and did not entertain taboos related to this. It was earlier argued that effective communication between parents and adolescents regarding sexual health and relationships is important, given the potential contribution to adolescents as far as the adoption of safer sexual behaviors is concerned [16]. Talking about sex was generally not taboo

in the communities, though this problem was not completely absent. The health system's contribution to SRH empowerment of adolescent girls was acknowledged, though a palpable proportion perceived it as inadequate or insufficient; the same applied to the school environment, where, in secondary school, this remained somewhat informal or embedded in some subjects, though teachers took personal initiatives in this respect. This corroborates other aspirations [17], arguing that the school environment's contribution to adolescents' SRH should not be limited to SRH education as generally prescribed in the school program but should also consider teachers' personal initiatives to counsel and help adolescents shape their attitudes and behaviors toward safer SRH practices.

With respect to individual indicators, adolescent girls acknowledged the importance of SRH education and the fact that it should not be taboo to talk about sex to adolescents; they had positive behavioral intentions as they felt predisposed to receive SRH education, and that they could adjust their sexual lives and felt stressor factors for self-adjustment such as stress and anxiety. However, qualitative data heavily highlighted low self-esteem and low self-efficacy, as shyness was often reported, thus aligning with other studies [13] that found that poor communication skills, social shyness, and lack of knowledge were potential barriers to a safer sexual life. Poor attitudes were also reported, especially when interacting with parents, as parents often face disdain from their children. Adolescent girls being exposed to rape and other traumatic experiences were highlighted by stakeholders. The alarm was raised earlier [18], and it was stressed that the rates of depression, anxiety, and suicidal tendencies remain high among adolescents when exposed to sexual abuse and teenage pregnancy. Stakeholders reported that adolescent girls engaged in sex for money, thus questioning the appropriateness and readiness of their behavioral intention. This is not peculiar to this study context, as it was earlier reported that young women expected money and material goods not only from older partners but also from agemates, and young men expected to give something for sex. Thus, “transactional sex” is more widely reflective of adolescent relationships [19]. Regarding the empowerment dimension, they acknowledged their ability to make informed SRH decisions, the availability of SRH information and services, the actual utilization of SRH resources or services, and the effectiveness of resources and services.

It was recommended that information availability and accessibility, education and communication (IEC) materials, peer education and activities to promote services, and the community-directed approach, supported by community health workers (CHWs), be enhanced to improve SRH among youth [20, 21]. In this study context, while the community-directed approach with CHWs alongside formal health personnel was acknowledged, limited resources and equipment were noted as drawbacks. The legal context was perceived as paying sufficient attention or acting as a deterrent to potential instigators of adolescent girls into risky sexual behavior. Adolescent girls were also knowledgeable of their basic rights in this respect, as they were generally aware of the fact that nobody should force them into having sex, that nobody has the right to abuse their private parts, the right to choose their life partner, and the right to SRH education. However, stakeholders described a confused, unstructured legal framework, and many were unaware of it. Among others, a major loophole was that although some unstructured laws and regulations existed, their effective implementation remained highly questionable [22]. The health system presented enormous assets toward fostering the SRH of adolescent girls. Adolescent girls reported that they could freely access health facilities, received systematic SRH counseling at the health center, and were sensitized on SRH by

community health workers and health personnel at the community level. Many received SRH education and counseling through various health system outreach mechanisms. Health personnel made many efforts but faced hurdles such as language barriers, equipment shortages, and difficulty reaching remote areas due to the crisis and poor road conditions during rainy seasons, as well as parents not having phones and poor mobile network coverage in some areas.

The availability of health services and counseling was among the recommended approaches to enhance healthy sexual and reproductive health [23, 24]; information, education, and counseling, as appropriate, on human sexuality and reproductive health are major components of sexual and reproductive rights [17]. Community and socio-cultural norms were generally conducive to a sound sexual and reproductive life for adolescent girls. Adolescent girls generally acknowledged that early sex, multiple partners, and premarital sex were taboo, unlike talking about sex. Among others, men were not actually tolerated for abusing girls sexually, and parents did not generally decide when a girl should get married and to whom. It was earlier emphasized that sociocultural norms such as parents' religious beliefs and cultural taboos are barriers that influence sexuality-related conversations among parents and adolescents [25-27]. However, several barriers to the sexual and reproductive health of adolescent girls were depicted by the study. In this conflict and fragility context, adolescent girls generally raised concerns about the fact that displacement to a different locality caused negative changes in their lifestyle, exposing them to risky sexual behavior, chaos, promiscuity, and lawlessness exposing youth to risky sexual behavior,; the same with hardship caused by the socio-political crisis in their family and social environment, which has also disrupted education, caused school dropout, and further exposed youth to risky sexual behavior.

Peer influence [28], low self-esteem, and social taboo were also highlighted. Stakeholders' perceptions of things that should be done to improve and sustain the sexual and reproduction empowerment of the adolescent girl ranged from sustained and early home-based education; sustained, early and comprehensive / intensified school-based education; sustained and intensified community-based education and awareness; education through mass media; church-based education; legal empowerment; providing needs; punitive measures; family planning; controlled social media; mood-oriented education; controlling the adolescent girl; regular screening; economic empowerment; support from NGOs; early vaccination and youth friendly health services; participatory approach by involving the young girls in education and sensitization programs. Young people's participation in the development, implementation, evaluation, and advocacy of AYSRHR interventions improves their effectiveness [21], so participatory approaches should give sufficient attention to integrating them into such programs at different levels.

Conclusion

SRH empowerment of adolescent girls was a major preoccupation for various stakeholders, who undertook proactive and reactive actions at different levels. Education on SRH mostly started at early adolescence, that is, between 10 and 13 years, because it is perceived as the reasoning age, the onset of puberty, and to enhance self-control. The unsafe and risky nature of the social environment that predisposed adolescent girls to unwanted pregnancy, risk of rape, and other sexual abuses, abortion and associated risk, as well as STIs and substance abuse was a salient triggered to SRH education of adolescent girls and was at the same time one of the main things stakeholders discussed with them besides enhancing ability to identify sexual predators and reporting, the aptitude to choose a partner,

cautioning on the risk of premature sex, the need for abstinence enhancing their ability to self-control and self-protection while raising awareness to the risk of unwanted pregnancy, STIs, peer pressure, teaching them signs of puberty as reflected on the body and associated risks, and how to care for the reproductive organs. Though evidence indicates that SRH empowerment was not actually a major problem in this study context, the impact was questionable, as though empowered, adolescent girls still indulged in sex relatively early. Among others, though adolescent girls generally said to be aware and to have access to either form of contraceptive methods, their willingness to use them was relatively low except for condoms. Teenage pregnancy was relatively high. Critical predictors of age at sexual debut were the inadequate economic emancipation of adolescent girls, the high vulnerability of those with dead parents, those in a single-mother home or living with a friend, and the conflict and fragility context. To improve and sustain the sexual and reproductive empowerment of adolescent girls, it was suggested sustained and early home-based education; sustained, early and comprehensive / intensified school-based education; sustained and intensified community-based education and awareness; and education through controlled mass media. Refining and structuring policies in a multi-sectoral collaborative dynamic is a prerequisite for achieving our vision of effective and sustainable SRHE for adolescent girls.

Limitations

This study was conducted in a region facing socio-political instability since 2016, which made working in rural/remote communities challenging. Despite these constraints, the study achieved its objectives.

Recommendations

To enhance the effectiveness of SRH empowerment of the adolescent girl, the following recommendations were made:

Ending the socio-political crisis rocking the region since 2016;

Enhancing education and awareness at home, in the community, in schools, in health centers, and through mass media and social media while controlling for unsuitable content;

Enhancing collaboration among stakeholders; and

Fostering a participatory approach in which adolescent girls are active actors where conducive, notably in actions geared toward enhancing their SRH empowerment.

Acknowledgements

The authors sincerely thank the study participants, research assistants, and Tiko District Health team members, as well as key informants at institutional, community, district, regional, national, and international levels, for their support and contributions to this research. Their dedication and collaboration were instrumental in successfully completing this study.

Disclaimer

The views and opinions expressed in the submitted article are the author's own and not the official position of the affiliated institutions.

Data Availability

Data for this study are available and can be accessed if requested.

Competing Interest Statements

The authors declare no competing interests regarding this study and publication, and all data used are available.

Author Contributions

Binsila B. B. and Bodzewan E.F. participated in all stages of this paper, from study design and methods to data collection,

analysis, and writing. Nana C. participated in methods and data analysis.

Ethical Approval

Ethical approval was obtained from the Southwest Regional Delegation of Public Health, Ref. No1292/CRERSH/SW/C/05/2026.

Funding

This study was conducted as part of a Ph.D. program and received no external funding from public, commercial, or non-profit organizations.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art026

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Women's Empowerment Measurement in Quantitative Reproductive Health Studies: From Unidimensional Proxies to a Multidimensional Framework

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Cite this article as: Waffo Uilrich Inespere, Samuel Nouetagni, Nguegang Tayou Sariette Agnes. Women's empowerment measurement in quantitative reproductive health studies: from unidimensional proxies to a multidimensional framework. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art026**

Article Type: Review Article

Received: 04.06.2026
Accepted: 13.08.2026
Published: 30.10.2026

Abstract *Women's empowerment is among the most studied determinants of reproductive health in low- and middle-income countries, yet quantitative reproductive health research continues to operationalise it through single proxies even though the construct is theoretically established as multidimensional. This reliance on unidimensional measurement misrepresents the construct and produces findings that are often inconsistent across settings. This review develops and defends a transparent, multidimensional framework for measuring women's empowerment from Demographic and Health Survey (DHS) data, grounded in Kabeer's resources, agency, and achievements model, and illustrates it using Cameroon DHS data. A structured narrative review informed the synthesis of six dimensions recurrent in reproductive health studies: economic, educational, sociocultural, reproductive, normative, and digital, each operationalised from standard DHS variables through a standardised additive scoring protocol. Measurement quality was assessed by distinguishing reflective from formative indices and by multicollinearity diagnostics. The framework was constructed on the 2018 Cameroon DHS (n = 4,449 partnered women aged 15–49 with a recent birth or pregnancy). The two reflective dimensions (educational, digital) met the $\alpha \geq 0.70$ threshold, the four formative dimensions were validated by construct coverage, and correlation and variance-inflation diagnostics confirmed that all six dimensions are statistically independent. Sub-dimension analysis revealed heterogeneity that a single index conceals, including a substantial digital access-and-use gap. A domain-differentiated additive framework is theoretically necessary, operationally achievable, and internally consistent within existing DHS infrastructure, preserving the dimension-specific effects essential for intervention design.*

Keywords *Additive Scoring, Demographic and Health Surveys, Digital Empowerment, Multidimensional Measurement, Reproductive Health, Women's Empowerment.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art026

Introduction

Few constructs in global public health carry the normative and analytical weight of women's empowerment. Since the International Conference on Population and Development (1994) and the Beijing Platform for Action (1995), empowerment has been treated simultaneously as a determinant of reproductive health, a development objective in its own right, and a marker of social progress [1, 2]. Associations between empowerment and maternal health, contraceptive uptake, fertility, and child survival have been documented across diverse country settings and three decades of research [3-5]. The direction of these associations is rarely disputed. What remains genuinely unsettled, and is too often left unexamined, is whether the variables routinely used to measure empowerment capture the construct that the introductions of those same studies invoke.

This gap is specific to public health, and within it to reproductive health, where the convenience and reach of Demographic and Health Survey (DHS) data have made single-proxy measurement the working norm even as neighbouring disciplines moved beyond it. Most quantitative reproductive health studies operationalise women's empowerment through a single variable, typically years of schooling, employment status, or participation in three named household decisions [3, 5, 6]. Yet empowerment is a multidimensional and dynamic construct, as Kabeer's foundational framework and subsequent researchers have shown [1, 7]. Kabeer defined empowerment as the capacity to make strategic life choices in contexts where that capacity was previously denied, distinguishing resources (the preconditions for choice), agency (the capacity to exercise it), and achievements (realized outcomes). This tripartite distinction makes explicit what single proxies conceal: possessing an educational or economic resource is not the same as possessing reproductive agency, and a measure that conflates the two is theoretically uninterpretable. Malhotra and Schuler [7] extended this critique into measurement practice, arguing that empowerment is irreducibly multidimensional.

Building on Kabeer's framework, women's empowerment in reproductive health can be operationalised as a set of distinct dimensions and sub-dimensions that stand in for the commonly used proxies. These dimensions can be constructed either through additive scoring or through factor-analytic methods such as principal component analysis (PCA) and multiple correspondence analysis (MCA). This paper develops the additive scoring approach and applies it illustratively to the 2018 Cameroon DHS.

The difficulty with prevailing measurement practice is structural rather than careless. The DHS programme provides the most comprehensive, nationally representative reproductive health data available in low- and middle-income countries and has become the default source for empowerment research. The DHS was designed, however, to measure fertility, family planning, and health service use, not to operationalise any particular theory of empowerment. The variables adopted as empowerment proxies were included because they correlate with demographic outcomes, not because they represent agency in Kabeer's sense [8]. Researchers borrowing these variables are therefore repurposing an instrument built for a different task.

This repurposing has consequences that accumulate at the level of the field. A study measuring empowerment through education will find that educated women have better reproductive outcomes but cannot determine whether bodily autonomy, financial independence, or digital access contributed independently. When studies using different single proxies are all labelled studies of women's empowerment, their results are not measuring the same construct and cannot be expected to agree [9]. The well-documented inconsistency of empowerment and health

findings across settings is, to a substantial degree, a measurement artefact.

Materials and Methods

Review Design and Search Strategy

This is a structured narrative review of the conceptualisation and operationalisation of women's empowerment in public health research, with an applied methodological focus on constructing empowerment measures from DHS data. PubMed, Google Scholar, and CINAHL were searched using combinations of the terms women's empowerment, empowerment measurement, operationalisation, proxy indicators, composite index, factor analysis, SWPER, digital empowerment, reproductive health, and sub-Saharan Africa. The search was not date-restricted in the first pass, which captured foundational theoretical works (notably Kabeer 1999 and Malhotra and Schuler 2005); a second pass restricted to 2016 to 2025 identified contemporary measurement debates and recent empirical applications. Studies were retained if they addressed empowerment conceptualisation or measurement, validated a measurement instrument, or examined empowerment and reproductive health associations in low- and middle-income settings.

Data Source

The construction proposals are based on the DHS programme's Individual Recode (IR) file. Variable references follow the standard DHS-7 questionnaire and are available in most country datasets fielded from 2015 onward, with the digital module available in the most recent rounds. The DHS is cross-sectional, so empowerment status is recorded at interview, contemporaneously with the reproductive history it is used to explain. To demonstrate that the framework is operational, the empowerment dimensions were constructed on the 2018 Cameroon DHS (CDHS-V), comprising 4,449 married or cohabiting women aged 15–49 with a birth or pregnancy in the three years preceding the survey.

All distributional estimates use the DHS individual sample weight (v005, rescaled by dividing by 1,000,000) to correct for the unequal selection probabilities of the survey's stratified, multistage cluster design. Variance estimation reflects that design by treating the survey strata (region by residence) and the primary sampling units (survey clusters) as the design structure, with standard errors obtained through Taylor-series linearization. All computations were carried out in R using the survey package, applying svydesign and its associated weighted tabulation functions.

One qualification applies to the reproductive empowerment dimension. Several of its healthcare-access items, specifically the questions on barriers to obtaining care such as distance, permission, and not wanting to go alone, were drawn from a survey module that was not administered to the full sample, so approximately half of respondents have no data on those items. Under the rule requiring at least 50% of a dimension's items to be valid, the reproductive dimension is therefore constructed on 1,061 women rather than the full analytical sample. This is a structural feature of the survey instrument rather than ordinary item non-response, and its consequences for interpretation are noted in the Limitations.

Construction and Validation Approach

The empowerment dimensions are built with a standardised additive scoring protocol and are then subjected to measurement validation before interpretation. The construction process and its difficulties are themselves a central object of this paper, since the labour of multidimensional measurement is a principal reason proxies persist. In outline, the protocol recodes all component items to a common ordinal scale, aggregates them into sub-dimension and domain indices as the mean of non-missing items, and assesses measurement quality through two complementary

procedures: an internal-consistency and dimensionality check that distinguishes reflective indices (assessed with Cronbach's alpha) from formative ones (validated by construct coverage), and a multicollinearity assessment (Spearman correlations and generalised variance inflation factors) that tests whether the dimensions are statistically independent.

Analytical and Theoretical Framework

Empowerment dimensions were conceptualised following Kabeer's resources, agency, and achievements model [1] and the multidimensional operationalisation logic of Malhotra and Schuler [7]. Each dimension is treated as analytically independent while acknowledging that dimensions are empirically interlinked. The central methodological question is this: once distinct dimensions are accepted, how should items within each dimension be combined, and how should the dimensions relate to one another analytically? The review first examines SWPER, then compares additive scoring and MCA, and finally presents the six-dimension framework that results.

Results and Synthesis

The Predominance of Unidimensional Proxy Measurement

The empirical literature on women's empowerment and reproductive health is dominated by studies that operationalise empowerment through a single DHS variable. In systematic reviews, Pratley [6] and Vizheh et al. [8] found that most instruments captured only one or two of the domains theory identifies as constitutive of empowerment, and that the domains most consistently omitted were those most proximal to reproductive decision-making: normative safety, bodily autonomy, and reproductive autonomy.

The most common proxies, educational attainment, employment status, and participation in household decisions, share three convenient properties: they are available in virtually every DHS dataset, they can be operationalised identically across countries, and each is genuinely associated with reproductive outcomes at the population level [3, 10, 11]. These properties explain the persistence of single-proxy measurement far better than any theoretical justification, because no serious theoretical account holds that empowerment is unidimensional.

There is a further, rarely stated reason for the dominance of proxies: multidimensional measurement is genuinely difficult to do well, and the difficulty is methodological rather than merely conceptual. A defensible multidimensional index requires the analyst to specify dimensions on theoretical grounds, assign many DHS items to the correct dimension and sub-dimension, settle on a consistent coding and aggregation scheme, choose between additive and factor-analytic construction, handle missing data and sparse categories, and then validate the result by distinguishing reflective from formative dimensions and testing the dimensions for redundancy. A single proxy sidesteps all of this: one variable, already cleaned and comparable, with a published precedent for its use. Faced with this asymmetry of effort, and with legitimate pressure to produce comparable, publishable results, many researchers reasonably default to the proxy. The construction protocol and validation procedure set out below are intended in part to lower that barrier, so that complexity becomes a reason to standardise the method rather than to abandon the ambition.

Why Unidimensional Approaches are Insufficient

The core problem is that proxies treat a resource as though it were the agency to use that resource. Kabeer's framework is explicit that resources are preconditions for choice, not choice itself [1]. A years-of-schooling variable measures the resource and is silent on the

normative, relational, and institutional conditions that convert it into reproductive agency. Malhotra and Schuler [7] argued that treating economic or educational variables as empowerment proxies assumes resource acquisition produces agency automatically, an assumption that fails systematically in patriarchal settings.

Empirically, Bayissa et al. [12] found that the association between economic empowerment and reproductive health outcomes weakened substantially once normative constraints were controlled. Das [13], using structural equation modelling, showed that adding freedom of movement and household decision-making as independent dimensions changed the entire predictive structure, revealing the conditions under which resources convert into agency. Single proxies cannot detect this conditionality, because the conditioning dimensions are left unmeasured and therefore uncontrolled.

Sharaunga et al. [14] identified a second failure: self-reported household decision-making cannot distinguish genuine negotiating authority from permitted participation. In high-fertility sub-Saharan African settings, this systematically overclassifies women as empowered and biases the proxy towards null associations.

A third failure is temporal misalignment. Because the DHS is cross-sectional, empowerment is recorded at interview, often after the reproductive events under analysis. The causal logic assumes that empowerment shapes subsequent reproductive decisions, yet the data capture a single instant, leaving a substantial share of reported associations vulnerable to reverse causation. This vulnerability is most acute for reproductive autonomy, decision-making participation, and economic control, each plausibly influenced by completed fertility as much as it influences it. No construction method examined in this review resolves this structural limitation of cross-sectional data.

SWPER: The Field's Attempt to Move Beyond Proxies

The most influential attempt to move beyond single proxies is the Survey-based Women's Empowerment Index for Africa (SWPER). Developed by Ewerling et al. [15] using DHS data from 34 sub-Saharan African countries, SWPER applies PCA to standard DHS items and retains three components: attitude to violence, social independence, and decision-making. It represents a genuine methodological advance, validated on a large, representative, multi-country dataset, standardised for cross-national comparison, and preserving a degree of domain differentiation.

SWPER nonetheless carries three residual limitations. Its three sub-scores aggregate conceptually distinct dimensions, folding much of the remaining content into social independence; its PCA-derived weights are optimized for cross-national structure, which supports comparability but obscures the dimension-specific effects essential for intervention design; and the digital dimension is absent entirely, because the relevant items did not exist in the DHS rounds on which SWPER was built. A high social-independence score, for instance, may reflect strong educational attainment with weak normative safety, or the reverse, and the two carry different implications for programming. SWPER and the domain-differentiated framework developed here are best understood as complementary instruments: SWPER for cross-national comparison and trend monitoring, the domain-differentiated framework for identifying which specific empowerment pathway to target in a given programme.

Empowerment Index Construction Approaches

Two strategies dominate the applied literature: additive scoring and, for categorical data, multiple correspondence analysis. Each rests on different assumptions and carries distinct strengths and limitations.

Additive scoring: This method assigns an ordinal value to each item, combines items within a dimension by summation or by the mean of non-missing items, and categorises continuous scores into ordered empowerment levels. Its strengths are full transparency, replicability, theory-led item assignment, natural handling of ordinal categorical items, and policy-legible categories. The equal-weighting assumption is a limitation, but it is mitigated when the index is accompanied by an internal-consistency check for reflective dimensions and can be validated further against factor-analytic solutions.

Multiple correspondence analysis: MCA is the categorical-data analogue of PCA, identifying latent axes that account for maximum inertia and yielding empirically derived weights. Its strengths are empirical weighting and the capacity to reveal dimensional structure. Its limitations are sample-dependent weights that undermine cross-national comparability, axes that may not align with theoretically meaningful dimensions, and reduced transparency for non-specialist audiences.

A pragmatic synthesis: Where the goal is theory-led, cross-nationally comparable, policy-legible measurement that preserves the independence of conceptually defined dimensions, additive scoring is preferable, with a factor-analytic check used to confirm dimensional coherence where the measurement model is reflective. The protocol adopted here employs additive scoring with a measurement-validation step that distinguishes reflective indices (assessed by Cronbach's alpha) from formative ones (validated by construct coverage), tests the dimensions for statistical independence, and allows category collapsing when sparse cells are encountered. This protocol was applied to the Cameroon DHS, with results reported below.

Main Empowerment Dimensions in Reproductive Health Studies

Applying this construction logic across the empowerment approaches used in reproductive health studies yields a six-dimension synthesis. Five dimensions (economic, educational, sociocultural, reproductive, and normative) are well established in the literature [7, 12]; the framework's contribution is to assemble them coherently, add the digital dimension, and specify their operationalisation from DHS variables. The six dimensions, their sub-dimensions, pathways, and principal measurement limitations are summarised in Table 1.

Economic empowerment encompasses employment agency, asset ownership, and financial inclusion, operating through household bargaining power [3, 11]; the DHS captures employment better than control over earnings.

Educational empowerment combines formal attainment and functional literacy. It delays marriage, raises the opportunity cost of childbearing, and expands knowledge [10, 16], but attainment is acquired years before reproductive decisions and is silent on the conditions of its deployment.

Sociocultural empowerment combines household decision-making autonomy and mass media exposure, operating through decision authority and informational exposure [14, 17, 18]; its decision-making items cannot separate genuine authority from conditioned compliance.

Reproductive empowerment is the dimension most proximal to fertility outcomes, encompassing contraceptive knowledge, autonomy over contraceptive decisions, unmet need, and permission to seek care. It consistently predicts modern contraceptive use [19, 20], and women's autonomy is linked to high-risk fertility behaviour in DHS-based analyses [21]; social desirability bias in patriarchal settings is its main measurement limitation.

Normative empowerment captures rejection of gender-based violence (GBV) justification, bodily autonomy, and freedom of movement, the structural conditions that enable the conversion of resources into agency [1, 22]; exposure to sexual violence is itself associated with elevated unmet need for contraception across sub-Saharan Africa [23]. Its attitudinal items capture acceptance of violence rather than experienced safety, and the behavioural intimate partner violence module is administered to a sub-sample only.

Digital empowerment is a substantive contribution of this framework. It encompasses mobile phone ownership and exposure to family planning information online (digital access) together with frequency of internet use and use for health information (digital use and engagement). The access-and-use distinction is critical: active, purposeful digital engagement, not mere ownership, carries the agency-relevant signal [24], and digital tools are increasingly used to deliver sexual and reproductive health information across sub-Saharan Africa [25].

The six dimensions are organized around Kabeer's resource-and-agency distinction: four are primarily resource dimensions (economic, educational, sociocultural, and digital), and two concern the proximate exercise of agency and its structural conditions (reproductive and normative). This echoes early multidimensional autonomy frameworks that treated decision-making, mobility, and economic autonomy as separable axes [26]. The number six is a hypothesis, and the internal-consistency and separability checks built into the protocol are designed to test it empirically.

Table 1. A Six-Dimension Framework for Women's Empowerment Measurement using DHS Data

Dimension	Sub-Dimensions	Pathway to Reproductive Health	Principal Measurement Limitation
Economic	Employment agency; asset ownership; financial inclusion	Household bargaining power; capacity to access services [3, 11]	Captures employment, not earnings control; wealth index is household-level [7]
Educational	Formal attainment; literacy	Delays marriage and first birth; raises opportunity cost [10, 16]	Resource acquired long before reproductive decision; silent on deployment
Sociocultural	Household decision-making; media exposure	Decision authority and informational exposure [14, 17, 18]	Cannot separate authority from conditioned compliance [14]
Reproductive	Contraceptive knowledge; decision-maker; unmet need; permission to seek care	Most proximal to fertility outcomes; contraceptive agency [19, 20]	Social desirability bias; autonomy over-reported in patriarchal settings [8, 9]
Normative	GBV-justification rejection; bodily autonomy; freedom of movement	Structural enabler of resource-to-agency conversion [1, 22]	Attitudinal, not experiential, safety; behavioural IPV module sub-sample only
Digital	Digital access; digital use and engagement	Informational exposure and active service navigation [24]	Newest dimension; access-and-use gap; absent from older DHS rounds and from SWPER

DHS = Demographic and Health Surveys; GBV = gender-based violence; IPV = intimate partner violence; SWPER = Survey-based Women's Empowerment Index for Africa.

An Illustrative Construction of the Six Dimensions with Cameroon DHS Data

Applying the protocol to the 2018 Cameroon DHS demonstrates that the full multidimensional construction runs end to end on real data. The analytical sample comprised 4,449 married or cohabiting women aged 15–49 with a birth or pregnancy in the three years preceding the survey, a restriction that narrows the temporal gap between empowerment measurement and the relevant reproductive behaviour. The resulting distributions, reliability, and independence of the six dimensions are reported below.

The Construction Protocol

Specifying the framework is only half the task; turning it into usable indices requires a construction protocol whose every step involves a judgement that a single proxy avoids. The protocol standardises construction across all six dimensions so that the indices are comparable and the procedure is replicable from the published scheme alone.

All component items are recoded to a consistent 0 to 3 scale on which higher values indicate greater empowerment; for items with fewer than four response categories, values are assigned to preserve relative distance (binary items, for example, are coded 0 and 3). Domain and sub-dimension scores are calculated as the arithmetic mean of non-missing component items, with a minimum of 50% of a domain's items required for a score to be computed. For descriptive use, continuous scores are categorised as not empowered (0.00), poorly empowered (0.01 to 1.50), empowered (1.51 to 2.50), and highly empowered (2.51 to 3.00). Each domain is initially coded as this four-category ordinal variable; where a category contains fewer than 2% of respondents, adjacent sparse categories are collapsed to ensure cell sizes adequate for stable estimation. The full coding scheme, item sources, scoring, and resulting final categories for every dimension are set out in Table 2.

Two challenges in this process deserve emphasis, because they are where multidimensional construction most often falters. The first is aggregation across heterogeneous items: a domain such as economic empowerment combines employment, asset ownership, and financial inclusion, components measured on different instruments and not interchangeable, so the mean-of-items rule must be defended as a deliberate formative aggregation rather than assumed. The second is the validation that must follow construction and that determines whether the indices can bear interpretive weight at all. Both are addressed in the validation results below, and both illustrate why a transparent, shared protocol is preferable to the bespoke, study-specific constructions that make multidimensional measures hard to compare and easy to contest.

Table 2. Index Construction Protocol: Variables, Coding, Score Calculation, and Final Categories

Sub-Dimension	DHS Variables	Item Coding (0–3)	Score Calculation	Final Categories
Economic Empowerment				
Employment agency	Occupation; employer type; earnings type; decision on earnings	0 = not working or not paid → 3 = professional or cash	Mean of non-missing items (min. 50%)	3 categories: Not/Poorly (≤1.50), Empowered (1.51–2.50), Highly (2.51–3.00)
Asset ownership	Owns land alone/jointly;	0 = does not own; 3 = owns alone or jointly		

	owns house alone/jointly			
Financial inclusion	Bank account; mobile money	0 = no; 3 = yes		
Educational Empowerment				
Formal schooling	Highest educational level; years of education	0 = no education → 3 = higher	Mean of non-missing items	4 categories: Not (0.00), Poorly (0.01–1.50), Empowered (1.51–2.50), Highly (2.51–3.00)
Literacy	Literacy test	0 = cannot read → 3 = reads multiple languages		
Sociocultural Empowerment				
Household decision-making	Decisions on healthcare, large purchases, family visits, partner's earnings	0 = husband alone → 3 = respondent alone	Mean of non-missing items (min. 50%)	4 categories: Not (0.00), Poorly (0.01–1.50), Empowered (1.51–2.50), Highly (2.51–3.00)
Media exposure	Frequency of newspaper, radio, TV	0 = not at all → 3 = almost every day		
Reproductive Empowerment				
Reproductive knowledge	Knowledge of contraceptive methods; ovulatory cycle	Methods: 0 = none → 3 = modern + traditional; cycle: 0 = no, 3 = yes	Mean of non-missing items (min. 50%)	Overall domain 2 categories: Not/Poorly/Empowered (≤2.50), Highly (2.51–3.00)
Reproductive autonomy	Contraceptive decision-maker; barriers (permission, distance)	Decision: 0 = partner → 3 = respondent + provider; barriers: 0 = major problem → 3 = not a problem		
Normative Empowerment				
Rejection of GBV justification	Beating justified if goes out, neglects children, argues, refuses sex, burns food	0 = yes (justified); 3 = no (not justified)	Mean of non-missing items (min. 50%)	Overall domain 2 categories: Not/Poorly/Empowered (≤2.50), Highly (2.51–3.00)
Bodily autonomy	Age at first cohabitation; age at first sex; spousal age difference	Age: 0 = <15 → 3 = 21+; spousal diff: 0 = 10 + yrs older → 3 = wife older or equal		

Digital Empowerment				
Digital access	Mobile phone ownership; FP information on internet/social media	0 = no; 3 = yes	Mean of non-missing items (min. 50%)	3 categories: Not/Poorly (≤1.50), Empowered (1.51–2.50), Highly (2.51–3.00)
Digital use and engagement	Internet frequency past month; used internet for health information	Frequency: 0 = not at all → 3 = almost daily; health info: 0 = no, 3 = yes		

FP = family planning; GBV = gender-based violence. Reliability and dimensionality of each index are reported in Table 3.

Source: author compilation from CDHS-V 2018.

Measurement Validation Results

Reflective and Formative Dimensions

Two measurement models must be distinguished, because they call for different validation criteria [27, 28]. In a reflective model the sub-dimensions are interchangeable manifestations of a single latent trait and are therefore expected to correlate strongly, so Cronbach's alpha is the appropriate reliability index. In a formative model the sub-dimensions are distinct, non-substitutable constituents that jointly define the construct and are not expected to correlate, so a low alpha reflects the formative structure rather than poor reliability, and validity rests instead on the theoretical completeness with which the sub-dimensions cover the construct. Each dimension was assigned to a measurement model a priori, from the theoretical relationship among its sub-dimensions, and the alpha coefficients were then used to confirm the reflective assignments rather than to determine the classification.

Internal consistency and the mean inter-sub-dimension correlation are reported in Table 3. The two dimensions specified as reflective exceed the conventional threshold: educational ($\alpha = 0.887$) and digital ($\alpha = 0.814$), confirming that their sub-dimensions measure a common latent construct and that alpha is the appropriate reliability index for them. The four dimensions specified as formative, sociocultural ($\alpha = 0.440$), normative ($\alpha = 0.146$), economic ($\alpha = 0.135$), and reproductive ($\alpha = 0.061$), show the low internal consistency that a formative structure predicts. Their sub-dimensions are distinct and non-substitutable: a woman may own assets without holding a bank account or reject the justification of gender-based violence without exercising bodily autonomy. The low inter-sub-dimension correlations ($r = 0.032$ to 0.282) are precisely the expected signature of formative measurement, not evidence of unreliability. For these dimensions, validity was assessed against construct coverage: the sub-dimensions were specified from theory to span the domain (for economic empowerment, employment, assets, and financial inclusion; for reproductive empowerment, knowledge, autonomy, and access), and their weak correlations confirm that each carries non-redundant information. The two reflective dimensions are therefore retained on their internal consistency and the four formative dimensions on their theoretical grounding and component coverage, consistent with established practice in empowerment measurement [1, 7].

Table 3. Internal Consistency and Dimensionality of the Empowerment Indices, CDHS-V 2018

Dimension	Sub-Dimensions	n	Inter-item r	Raw α	Std. α	Index type
Educational	Schooling, literacy	4,434	0.796	0.884	0.887	Reflective
Digital	Access, use	4,449	0.687	0.701	0.814	Reflective

Sociocultural	Decision-making, media	4,449	0.282	0.431	0.440	Formative
Normative	GBV rejection, bodily autonomy	4,433	0.079	0.105	0.146	Formative
Economic	Employment, assets, finance	3,393	0.049	0.096	0.135	Formative
Reproductive	Knowledge, autonomy, access	1,061	0.032	0.045	0.061	Formative

Std. α = standardised alpha; inter-item r = mean inter-sub-dimension correlation. Reflective dimensions meet α ≥ 0.70 and are retained on internal consistency; formative dimensions are validated by construct coverage. The reduced reproductive n reflects structural missingness in the healthcare-access sub-dimension.

Source: author construction from CDHS-V 2018.

Statistical Independence of the Dimensions

The distinctness on which the framework rests is testable, and it is supported by two multicollinearity diagnostics (Tables 4 and 5). In the Spearman rank correlation matrix, no dimension pair reached the $|\rho| = 0.70$ flag; the strongest associations were educational and sociocultural (0.605) and educational and digital (0.603), both well below the threshold, while economic empowerment correlated only weakly with every other dimension (0.151 to 0.290). The generalised variance inflation factors reinforce this: every variance-inflation equivalent fell between 1.24 and 1.44, far below the value of 5 that would indicate problematic collinearity. The six dimensions are therefore not merely conceptually distinct but statistically independent, each contributing non-redundant information.

Table 4. Spearman Rank Correlation Matrix among the Empowerment Dimensions, CDHS-V 2018

Dimension	**Econ.**	**Educ.**	**Socio.**	**Repro.**	**Norm.**	**Digital**
Economic	1.000	0.234	0.290	0.223	0.151	0.191
Educational	0.234	1.000	0.605	0.494	0.499	0.603
Sociocultural	0.290	0.605	1.000	0.473	0.442	0.478
Reproductive	0.223	0.494	0.473	1.000	0.530	0.386
Normative	0.151	0.499	0.442	0.530	1.000	0.415
Digital	0.191	0.603	0.478	0.386	0.415	1.000

Flag threshold $|\rho| > 0.70$ (none observed).

Source: *author construction from CDHS-V 2018.*

Table 5. Generalised Variance Inflation Factors for the Empowerment Dimensions, CDHS-V 2018

Empowerment Dimension	**GVIF**	**df**	**VIF-equivalent**	**Assessment**
Economic	1.907	3	1.240	No multicollinearity
Educational	2.868	3	1.421	No multicollinearity
Sociocultural	2.361	3	1.332	No multicollinearity
Reproductive	2.997	3	1.442	No multicollinearity
Normative	2.304	3	1.321	No multicollinearity
Digital	2.037	2	1.427	No multicollinearity

Rule: VIF-equivalent < 5 = none; 5–10 = moderate; > 10 = severe. VIF-equivalent = $(GVIF^{\wedge}(1/2 \cdot df))^2$.

Source: *author construction from CDHS-V 2018.*

Taken together, these diagnostics provide convergent evidence that the six-dimension structure is empirically defensible on these data: the reflective dimensions cohere internally, the formative dimensions carry non-redundant components, no dimension pair is collinear, and, as shown next, the sub-dimension distributions diverge sharply from their domain scores. This evidence is drawn from a single national dataset. Full confirmatory validation, including item-level factor analysis and measurement-invariance testing across multiple country settings, is the necessary next step and lies beyond the scope of this illustrative construction.

Distribution Across Dimensions and Sub-Dimensions

The constructed dimensions reveal substantial and policy-relevant unevenness (Table 6). Economic empowerment is the most polarized: 29.3% of women are not empowered, 25.8% poorly empowered, 21.7% empowered, and 23.2% highly empowered. Sub-dimension analysis shows that this overall profile conceals severe asset deprivation (83.6% low asset ownership) and limited financial inclusion (75.1% low), signals that a single economic score would average away.

Educational empowerment is more favourable (35.6% empowered, 14.1% highly empowered), but literacy remains a constraint for 37.9% of women, and 26.1% have no formal education. Sociocultural empowerment shows 44.1% of women in the empowered category for household decision-making, yet only 9.2% at the highest level, while 44.7% are not empowered on media exposure, two distinct pathways that a combined sociocultural score would blur.

Reproductive empowerment, collapsed to a two-category variable because of sparse intermediate cells, shows 26.2% of women highly empowered. Sub-dimension analysis locates the binding constraint precisely: 47.5% have high contraceptive knowledge and 39.0% report high reproductive autonomy, but 59.8% are in the low category for contraceptive access and use. The gap is in access, not in knowledge or autonomous decision-making, a distinction with direct programmatic implications.

Normative empowerment, also collapsed to two categories, shows 26.3% of women highly empowered. Rejection of gender-based violence justification is relatively widespread (69.8% moderate or high rejection), but bodily autonomy remains less consolidated, with a quarter of women not empowered. Digital empowerment is distributed across three categories: 41.4% not or poorly empowered, 36.3% empowered, and 22.3% highly empowered. The digital-use sub-dimension is striking: 83.1% of women exhibit low digital use, compared with 41.4% with low digital access, directly quantifying the access-and-use gap and confirming that mobile ownership alone is an insufficient indicator of digital agency. Across all dimensions, sub-dimension distributions diverge sharply from overall domain scores, which is the empirical justification for retaining them as separate analytical entities.

Table 6. Distribution of Women Across Empowerment Categories for the Six Dimensions and Sub-Dimensions, CDHS-V 2018 (N = 4,449)

Dimension / Sub-Dimension	Category	%
Economic Empowerment		
Overall index	Not empowered	29.3
	Poorly empowered	25.8
	Empowered	21.7
	Highly empowered	23.2
Employment agency	Not/poorly	44.5

	Empowered	28.0
	Highly	27.5
Asset ownership	Low	83.6
	Moderate/high	16.4
Financial inclusion	Low	75.1
	Moderate/high	24.9
Educational Empowerment		
Overall index	Not empowered	25.1
	Poorly empowered	25.3
	Empowered	35.6
	Highly empowered	14.1
Schooling	Not empowered	26.1
	Poorly empowered	18.2
	Empowered	41.7
	Highly empowered	14.0
Literacy	Not empowered	37.9
	Poorly empowered	11.9
	Empowered/highly	50.2
Sociocultural Empowerment		
Overall index	Not empowered	25.0
	Poorly empowered	22.7
	Empowered	30.1
	Highly empowered	22.2
Household decision-making	Not empowered	30.9
	Poorly empowered	15.7
	Empowered	44.1
	Highly empowered	9.2
Media exposure	Not empowered	44.7
	Poorly empowered	7.6
	Empowered	22.0
	Highly empowered	25.7
Reproductive Empowerment		
Overall index (collapsed)	Not/Poorly/Empowered	73.8
	Highly empowered	26.2
Contraceptive knowledge	Moderate	52.5
	High	47.5
Reproductive autonomy	Not empowered	25.2
	Poorly empowered	26.1
	Empowered	9.6
	Highly empowered	39.0
Contraceptive access/use	Low	59.8
	Moderate/high	40.2
Normative Empowerment		
Overall index (collapsed)	Not/Poorly/Empowered	73.7

	Highly empowered	26.3
GBV-rejection attitudes	Low rejection	30.2
	Moderate/high rejection	69.8
Bodily autonomy	Not empowered	25.1
	Poorly empowered	22.7
	Empowered	27.2
	Highly empowered	25.1
Digital Empowerment		
Overall index	Not/poorly empowered	41.4
	Empowered	36.3
	Highly empowered	22.3
Digital access	Not/poorly	41.4
	Empowered	36.6
	Highly	22.1
Digital use	Low	83.1
	Moderate/high	16.9

Categories were collapsed per protocol when a category held fewer than 2% of cases: the reproductive and normative overall indices to two categories, the economic and digital to three, and the educational and sociocultural retained four. Percentages are weighted.

Source: *author construction from CDHS-V 2018.*

Discussion

The trajectory this review traces, from single-proxy measurement, through SWPER's partial multidimensional solution, to a fully domain-differentiated framework with a transparent construction protocol, converges on a conclusion that is at once obvious and routinely neglected: women's empowerment cannot be adequately measured by any single DHS variable. Evidence from single-proxy studies should be read as evidence about that specific dimension, not about empowerment. The move towards multidimensional measurement is both theoretically necessary and practically achievable within existing DHS infrastructure, as the Cameroon illustration demonstrates.

Kabeer's framework [1] and Malhotra and Schuler's operationalisation critique [7] explain why. Resources are preconditions for choice, not choice itself, and the conditions that allow resources to convert into agency are an essential part of what empowerment means. The additive scoring protocol makes this theoretical commitment transparent: items are assigned to dimensions on conceptual grounds, equal weighting is explicit, and the indices are fully replicable from published coding schemes. The measurement-validation step is more discriminating than a blanket reliability rule: it recognises that two dimensions (educational and digital) are reflective and cohere internally, while the other four are formative, their sub-dimensions distinct and non-substitutable by design, so that a low alpha is expected and construct coverage is the proper criterion. The correlation and variance-inflation diagnostics then show the six dimensions to be statistically independent, supplying the empirical separability evidence that the distinctness claim requires and that aggregated indices cannot offer.

The comparison between additive and factor-analytic construction speaks directly to the most honest explanation for the persistence of single proxies: that multidimensional construction is hard. Reliance on proxies is not simply intellectual inertia but a rational response to the real effort that defensible

multidimensional measurement demands. The contribution of a standardised, transparent protocol is to convert that effort from a bespoke undertaking, repeated and contested in every study, into a replicable procedure that offers a pragmatic middle path of theory-led construction with empirical discipline.

The inclusion of digital empowerment is a substantive contribution. As mobile connectivity expands rapidly across sub-Saharan Africa, the youngest cohort of women is forming reproductive preferences in an informational environment no previous generation experienced. The Cameroon data reveal a striking access-and-use gap: 83.1% of women show low digital use even though only 41.4% lack digital access. This confirms that mobile phone ownership is a necessary but insufficient condition for digital agency, and that active, purposeful engagement is what matters for reproductive health information and service navigation. Omitting this dimension from standard instruments, including SWPER, leaves a potentially protective influence on reproductive outcomes unmeasured.

The temporal-misalignment finding carries the broadest implication of the review, reaching well beyond women's empowerment. Any determinant of health measured at the same interview as the outcome it is meant to explain, which describes much of the social-determinants-of-health literature built on DHS and comparable cross-sectional surveys, faces the same threat to causal interpretation. Future research should treat temporal alignment as a design question: favouring longitudinal designs where feasible, dating the determinant relative to the outcome and restricting analysis to determinants that demonstrably precede it, or, at minimum, stating plainly that directionality is unestablished. The dimensions most exposed to reverse causation, namely reproductive autonomy, decision-making participation, and economic control, warrant the most caution. Better measurement of empowerment, the central argument of this review, does not by itself resolve when empowerment is measured; both must be addressed for the evidence base to support the causal claims it routinely makes.

Limitations

Several limitations bound the strength of these claims. First, the empirical demonstration rests on a single dataset, the 2018 Cameroon DHS. The reliability, independence, and distributional evidence reported here establish that the framework is operational and internally coherent in this setting, but they do not amount to full psychometric validation; item-level confirmatory factor analysis and cross-country measurement-invariance testing remain to be carried out, and the six-dimension structure should be regarded as empirically supported rather than definitively confirmed. Second, the reproductive empowerment dimension is constructed on a reduced sample (n = 1,061), because its healthcare-access items were not administered to all respondents, so its distribution is measured less precisely than the other dimensions and should be read with corresponding caution. Third, the analytical sample is restricted to married or cohabiting women with a recent birth or pregnancy, a restriction chosen to narrow the temporal gap between empowerment and reproductive behaviour; the resulting distributions therefore describe partnered, recently childbearing women and should not be generalised to never-married or formerly partnered women, whose empowerment profiles may differ. Finally, as the review itself emphasises, the cross-sectional DHS design cannot establish that empowerment precedes the outcomes it is used to explain; better measurement addresses what is measured, not when.

SWPER moved the field decisively beyond single proxies, and the framework proposed here builds on that achievement. The remaining difference is one of analytical purpose: SWPER's aggregation serves comparability and trend monitoring, while the domain-differentiated framework serves the

identification of which specific empowerment pathway is the binding constraint in a given setting. Researchers should choose their instrument according to their question and should be explicit about which dimension of empowerment they actually measured.

Conclusion

The dominance of unidimensional proxy measurement in reproductive health empowerment research is an inheritance from the DHS tradition rather than a considered methodological choice. It has produced a large and valuable body of comparative evidence that is nonetheless insufficient for the theoretical claims it is used to support. Kabeer's resources, agency, and achievements framework and Malhotra and Schuler's operationalisation critique provide the conceptual tools to understand why, and the six-dimension framework set out here demonstrates that rigorous, internally coherent multidimensional measurement is achievable within DHS data using a transparent additive protocol. Constructed illustratively on Cameroon DHS data, the framework produced six distinct and interpretable empowerment distributions, including a digital dimension no existing index captures; its reflective dimensions met the $\alpha \geq 0.70$ threshold, its formative dimensions were validated by construct coverage, and correlation and variance-inflation diagnostics confirmed that the six dimensions are statistically independent. The central conclusion is simple: no single dimension, and no single aggregated score, adequately represents women's empowerment. Multidimensional, domain-specific measurement is closer to the reality of women's lived experience of power and constraint, and it is essential for designing public health interventions that address the right mechanisms in the right contexts. Measuring the right dimensions, and measuring them in the right temporal order, are both necessary if the field is to support the causal claims it routinely makes.

Conflict of Interest

The authors declare no conflict of interest.

Ethical Approval

Not applicable. This is a narrative review of published literature combined with secondary analysis of the publicly available, de-identified 2018 Cameroon DHS dataset. Ethical clearance for the parent survey was granted by the Cameroon National Ethics Committee for Human Health Research.

Author Contributions

Waffo Uilrich Inespere: conceptualisation, literature review, methodology, formal analysis, writing (original draft). Samuel Nouetagni: supervision, methodology, review and editing. Nguegang Tayou Sariette Agnes: empowerment-measurement analysis, writing (review and editing). All authors read and approved the final manuscript.

Data Availability

The DHS datasets analysed in this review are publicly available through the DHS Programme data repository at https://dhsprogram.com upon registration and completion of the standard data-access request. No new datasets were generated.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Acknowledgements

The authors acknowledge the support of the Texila American University doctoral programme.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art027

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Optimizing LTE Deployment through 1800 MHz Spectrum Refarming: Empirical Evidence from AirtelTigo Network in Ghana

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Cite this article as: Albert Neequaye Kotey. Optimizing LTE deployment through 1800 MHz spectrum refarming: empirical evidence from AirtelTigo network in Ghana. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art027**

Article Type: Review Article

Received: 13.07.2026
Accepted: 25.08.2026
Published: 30.10.2026

Abstract *The rapid growth of mobile data consumption has intensified pressure on limited radio spectrum resources, compelling mobile network operators to improve capacity, throughput, and Quality of Service (QoS) without acquiring additional spectrum. Spectrum refarming has emerged as a strategic solution that reallocates underutilized legacy spectrum to advance mobile technologies, thereby enhancing spectrum utilization and network performance. This study investigates the effectiveness of spectrum refarming in improving fourth-generation (4G) network capacity and QoS within AirtelTigo Ghana. A mixed-methods approach was adopted, combining technical drive test measurements, benchmarking of legacy network performance, network Key Performance Indicator (KPI) analysis, and a structured user perception survey. Drive tests were conducted across selected high-traffic urban locations to evaluate throughput, accessibility, coverage, and session stability, while a technical assessment of AirtelTigo's GSM 1800 MHz spectrum identified opportunities for reallocating a 5 MHz carrier for LTE deployment. The findings demonstrate that refarming the GSM 1800 MHz band enables the deployment of an LTE carrier that significantly improves downlink throughput, network capacity, and user experience without compromising legacy network performance. The results further indicate improvements in spectrum utilization, reduced network congestion, enhanced accessibility, and better overall QoS, leading to a more reliable and efficient mobile broadband service. The study concludes that spectrum refarming is a technically feasible and cost-effective modernization strategy for mobile network operators, particularly in spectrum-constrained developing markets, as it maximizes the value of existing spectrum assets while supporting growing broadband demand and delaying the need for costly acquisition of additional spectrum resources.*

Keywords *4G LTE, Network Capacity, Quality of Service, Spectrum Refarming, Underutilized Frequency.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art027

Introduction

The exponential growth of mobile data driven by smartphone penetration, high bandwidth applications, and IoT has created an unprecedented shortage of radio spectrum, particularly in the cellular bands [1]. The early standards (GSM, UMTS) operated under fixed, exclusive license models, which now struggle to accommodate demand. Existing solutions such as dynamic spectrum sharing and carrier aggregation offer incremental gains, but acquiring new spectrum licenses remains costly and slow. The best current solution for many operators is spectrum refarming, reallocating legacy bands (e.g., 1800 MHz from GSM to LTE) which is cost effective and avoids new licenses [2]. However, refarming has limitations: it requires careful interference management, gradual migration of legacy users, and compliance with residual coverage obligations (e.g., maintaining 2G/3G for rural areas). Despite these challenges, achievements are significant. Studies [3] show that refarming the 1800 MHz band can dramatically improve downlink throughput and QoS, and competitive mobile markets have continuously upgraded service levels without new spectrum. The objective of this study is to explore the technical, economic, and regulatory role of spectrum refarming in enhancing 4G capacity and improving QoS, using a real world operator case study in a developing market. The novelty lies in integrating technical drive tests, user perception surveys, and spectrum holding reviews within a live African network (AirtelTigo), bridging a gap in literature focused predominantly on developed regions [4].

Study Limitations and Key Constraints

Every research study encounters challenges that may affect the scope, methodology, and generalizability of findings. This study on "The Use of Spectrum Refarming to enhance 4G Capacity and Improve Quality of Service in Mobile Telephony" is no exception. Despite its significance, the research is subject to several limitations, categorized under technical, regulatory, economic, and methodological constraints [5]. Furthermore, AirtelTigo was unable to provide pre-simulation output data due to technical challenges with its asset planning tool, constraining the ability to validate spectrum-carving scenarios through predictive modeling. These limitations provide background for interpreting the findings and highlight grey densely populated regions and areas for future research.

In summary, although carving out 5 MHz for LTE was proposed as a quick capacity enhancement measure, benchmarking indicates that the narrow bandwidth would deliver only modest and short-term improvements. The main constraints are limited capacity headroom, legacy network coexistence and outdoor performance challenges. For meaningful and sustainable QoS improvement in high-traffic areas of Accra, wider contiguous LTE bandwidth, additional spectrum resources, and network densification would be required beyond the proposed 5 MHz refarming [6].

Evolution of Spectrum Refarming Practices in Mobile Networks

Modern spectrum refarming builds on historical transitions in mobile telephony, beginning with the reallocation of frequencies from 2G and 3G systems towards more spectrally efficient technologies. The literature highlights how legacy systems such as GSM, operating at 900 MHz and 1800 MHz, were gradually superseded by LTE deployments in the same bands, improving spectral efficiency and reducing operational overheads [7]. This transition exemplifies how spectrum refarming became an operational necessity, enabling operators to sunset underutilized technologies while simultaneously improving service delivery. Empirical findings demonstrate that LTE refarming offers substantial gains in throughput and latency reduction compared to legacy systems. [8] emphasize that LTE's

reliance on orthogonal frequency division multiple access (OFDMA) and support for multi-antenna techniques allows for significantly higher data rates within refarmed bands. Similarly, studies by Ref. [6] underscore the benefits of carrier aggregation, which enables operators to combine refarmed low-frequency bands with higher-frequency allocations to achieve broader bandwidth and more resilient connectivity. These answers establish that the state of the art in spectrum refarming is inseparable from broader advancements in LTE technologies.

Spectrum Sharing and Efficiency

Spectrum refarming has emerged as a strategic approach for improving the efficiency, performance, and economic sustainability of modern mobile networks. The principal achievements of spectrum refarming in 4G LTE and 5G deployments include the following:

Achievements of Spectrum Refarming in 4G & 5G

1. Cost Efficiency: Spectrum refarming enables mobile network operators (MNOs) to repurpose existing spectrum assets rather than acquire new frequency licenses. This approach significantly reduces capital expenditure (CAPEX) associated with spectrum acquisition while maximizing the utilization of existing spectrum resources [9].
2. Cost-Effectiveness: By reallocating legacy spectrum to LTE and 5G services, operators can increase network capacity and improve service delivery without participating in costly spectrum auctions. Consequently, spectrum refarming provides an economically viable solution for network modernization, particularly in spectrum-constrained markets [10].
3. Accelerated 5G Deployment: Spectrum refarming facilitates faster deployment of 5G networks by migrating spectrum from legacy technologies such as GSM and UMTS to New Radio (NR). This enables operators to expand 5G services more rapidly while meeting the growing demand for enhanced mobile broadband [11].
4. Optimized Spectrum Utilization: Dynamic spectrum refarming improves overall spectrum efficiency by reallocating underutilized frequency bands to technologies with higher traffic demand. This enhances spectral efficiency, increases network flexibility, and reduces operational costs through more effective resource utilization [11].
5. Improved LTE/5G Coverage and Network Capacity: Reallocating spectrum from legacy networks to LTE and 5G improves radio propagation characteristics, expands geographical coverage, and increases network capacity. These enhancements enable operators to deliver more reliable services while accommodating higher user densities and increasing data traffic [12].
6. Enhanced Quality of Service (QoS): Spectrum refarming contributes to improve network performance by reducing call drops, increasing data throughput, lowering latency, and enhancing overall user experience. These improvements are reflected in key Quality of Service (QoS) indicators such as accessibility, retainability, and mobility performance [13].

Purpose of the Study

This research critically examines spectrum refarming as a means of enhancing 4G mobile network capacity and quality of service (QoS). Spectrum refarming, involving the reallocation of 2G and 3G bands for advanced technologies, offers a strategic solution for improving spectrum utilization and network performance [14]. The study explores both technical and regulatory dimensions of refarming to assess its effectiveness. Ultimately, it aims to provide a comprehensive understanding of its role in

optimizing LTE networks and informing mobile policy and planning [15].

General Objective

This research critically examines spectrum refarming as a means of enhancing 4G mobile network capacity and quality of service (QoS). Spectrum refarming, involving the reallocation of 2G and 3G bands for advanced technologies, offers a strategic solution. The study explores both technical and regulatory dimensions of refarming to assess its effectiveness. Ultimately, it aims to provide a comprehensive understanding of its role in optimizing LTE networks and informing mobile policy and planning.

Specific Objectives

OBJ1: To evaluate the strategies and techniques for applying spectrum refarming to enhance 4G network capacity, specifically through increased spectral efficiency and the reallocation of legacy frequency bands to bolster LTE performance.

OBJ2: To assess the impact of spectrum refarming on key Quality of Service (QoS) metrics, including latency, throughput, call drop rates, QoS, Coverage and the resultant improvements in mobile user experience.

OBJ3: To identify and critically analyze the economic, technical, and regulatory challenges inherent in deploying spectrum refarming, encompassing cost-benefit implications, technical barriers during reallocation, and the influence of policy frameworks on implementation success.

OBJ4: To examine the conceptual foundations and historical evolution of spectrum refarming, contextualizing its strategic application and developmental trajectory within contemporary 4G mobile telephony networks.

OBJ5: To propose an integrated, multidimensional framework that synthesizes technical, regulatory, and economic perspectives, thereby providing a structured, evidence-based model for effective spectrum refarming to enhance 4G capacity and QoS.

Materials and Methods

Research Design

The research design adopted for this study is structured to systematically examine the role of spectrum refarming in enhancing 4G capacity and quality of service (QoS) within the context of mobile telephony. Given the dual technical and regulatory nature of spectrum refarming, the study adopts a mixed-methods research design that provide a holistic understanding of the subject. This design ensures that the technical performance of refarmed spectrum is evaluated empirically through field measurements and benchmarking, while also accounting for policy, economic, and operational dimensions through expert insights and contextual analysis [16, 17]. At the quantitative level, the research employs experimental and quasi experimental techniques by analyzing benchmark drive test data and conducting real-time drive tests in selected locations, including Accra Mall, 3 Junction, and West Hills Mall. These locations were purposefully chosen to represent different propagation environments, thereby enabling a comparative assessment of coverage, capacity, and QoS metrics. The study focuses on the reallocation of a 5 MHz block from GSM 1800 MHz spectrum to LTE, a process that illustrates the operational dynamics of spectrum refarming in practice [18, 19]. The quantitative data derived from these tests comprising throughput, latency, call drop rate, and signal strength provide measurable indicators of the improvements in capacity and service delivery resulting from refarming [1, 11]. Complementing the quantitative analysis, the research design incorporates qualitative insights obtained from a structured, closed-ended survey administered to individuals with backgrounds in telecommunications, IT, and engineering. The survey is designed to capture perceptions, expert evaluations, and

professional judgments on the feasibility, challenges, and benefits of spectrum refarming in the Ghanaian mobile telephony landscape. This element enriches the study by providing context to the technical results and situating them within broader considerations of regulatory frameworks, cost implications, and market dynamics [20, 21]. The outdoor testing with survey based expert inputs ensures triangulation, enhancing the validity and reliability of the findings [22]. The design further employs comparative analysis, evaluating the performance of AirtelTigo's network against existing deployments by other operators such as MTN and Telecel. This comparative dimension not only highlights the relative improvements made possible to be achieved by refarming but also emphasizes the areas requiring further investment to achieve parity in service quality across providers [1, 23].

By combining empirical field testing with expert perspectives and policy analysis, the chosen research design will achieve balance between technical precision and practical relevance. This will enable the study to move beyond theoretical discussions of refarming to demonstrate its tangible impact on network performance and user experience. At the same time, the research design acknowledges the broader economic and regulatory considerations that influence the effective implementation of spectrum refarming strategies [24]. In doing so, the research design provides a robust foundation for answering the central research questions and for generating insights that are both academically rigorous and practically applicable to the mobile telecommunications industry.

Research Approach

The study provides mixed-methods design which enables triangulation cross-verification of findings from drive tests, user surveys, and document analysis enhancing the validity and reliability of conclusions. This integration ensures that objective network performance data are complemented by subjective user perceptions and contextualized within regulatory and economic frameworks. The approach directly addresses methodological gaps in existing literature, which have predominantly relied on isolated assessments rather than integrated analysis [25, 26].

Consistent with the pragmatist research philosophy, this design permits the employment of the most appropriate methods for each research question, producing findings that are both academically rigorous and practically relevant. By grounding the research in a mixed-methods framework, the study offers actionable recommendations supported by both statistical evidence and contextual understanding, bridging the gap between technical evaluation and practical industry considerations.

Drive Test and Benchmark Data Collection

The primary quantitative data for this research was obtained from network drive tests and benchmark reports. AirtelTigo (AT) provided drive test data from a refarmed 5 MHz block in the GSM 1800 MHz band, which was reallocated for LTE use. Additionally, real-time drive tests were conducted by the researcher at key urban sites in Accra, including the Accra Mall, 3 Junction, and West Hills Mall. These sites were selected due to their high data demand and the presence of co-located networks such as MTN and Telecel, making them critical points for evaluating LTE performance. The data collected focused on throughput, latency, and call drop rates, which are globally recognized as key QoS metrics.

Closed-Ended Survey Design

In addition to empirical network data, a closed-ended survey was conducted targeting participants with professional backgrounds in telecommunications, IT, and engineering. The survey was designed to collect structured responses on participants' perceptions of

spectrum refarming and its potential to improve 4G capacity and QoS. Closed-ended questions were used to ensure uniformity in responses and facilitate statistical analysis. This methodological choice aligns with [27] Bryman (2016), who highlights that structured surveys enable researchers to quantify stakeholder perspectives, making the findings generalizable across similar contexts. The survey results were then triangulated with network performance data to provide a comprehensive view of both technical and industry perceptions regarding spectrum refarming.

Research Instruments

The research employed a combination of technical measurement tools and survey-based instruments to collect data that reflect the quantitative dimension of spectrum refarming in enhancing 4G capacity and quality of service (QoS). The choice of instruments were guided by the need to capture objective performance metrics of the refarmed spectrum while also eliciting expert opinions from professionals in telecommunications, IT, and engineering. This multi-instrument approach ensured that the study addressed the technical, experiential, and contextual aspects of spectrum refarming comprehensively. For the quantitative dimension, drive test equipment was the primary research instrument. The benchmark drive test relied on industry standard tools, including spectrum analyzers, scanning receivers, and test handsets equipped with specialized software such as PHU, TEMS Investigation and Nemo Outdoor, which are widely used in telecommunications research and commercial network performance evaluations [8]. These instruments enabled the measurement of critical network performance indicators such as throughput, latency, signal strength (RSCP), signal quality (Ec/Io), and call drop rate. The real-time drive tests conducted at Accra Mall, 3 Junction, and West Hills Mall allowed for a comparative analysis outdoor network environment, highlighting the impact of spectrum refarming on coverage and capacity. These instruments were selected due to their precision and reliability in producing repeatable measurements, which is essential for evaluating the performance improvements resulting from the reallocation of the 1800 MHz GSM spectrum to LTE. In addition to the technical measurements, a structured closed-ended questionnaire was designed as the quantitative research instrument to gather expert perspectives. This survey was administered to respondents with professional backgrounds in telecom engineering, IT, and network planning. The questionnaire was structured to cover key themes such as the perceived benefits of spectrum refarming, anticipated challenges in deployment, and views on the regulatory and economic implications. Using closed-ended questions ensured consistency in responses, allowing for easier quantification and statistical analysis, while also minimizing researcher bias [5]. The instrument was pilot-tested with a small group of respondents to refine its clarity and reliability before full deployment. The integration of drive test equipment and structured questionnaires provided a robust and complementary set of instruments. While the drive tests captured empirical performance data, the questionnaires contextualized these findings within the lived experiences and professional insights of stakeholders. This dual-instrument approach is consistent with best practices in mixed-methods research in telecommunications, where the combination of technical field measurements and expert perspectives leads to a more comprehensive understanding of network performance and spectrum policy implications [28, 29].

Moreover, online questionnaires were used as primary research instrument for data collection. The questionnaires were designed for closed-ended question and multiple questions which allow participants and professionals in the telecommunication sector, including telecom engineers, regulators and IT

professionals, regarding their perception on spectrum refarming and its impact on 4G network performance in relation to capacity, coverage and QoS.

Results & Discussion

Key Results from Google Forms Survey

In this final chapter, key findings were synthesized from the analysis of stakeholder perspectives on spectrum refarming, drawing together the technical, operational, and regulatory insights gathered through the survey conducted for this research. The study reflects on how these findings address the original research questions about enhancing 4G capacity through strategic spectrum reallocation. Practical recommendations were provided for implementing spectrum refarming initiatives, discuss the limitations of the study, and suggest valuable directions for future research that could build upon these findings. The survey of 44 telecommunications professionals revealed several critical insights that directly inform spectrum refarming strategies.

The study explored stakeholders' perception on the role of spectrum refarming in enhancing 4G network capacity and improving QoS and responses to questionnaires from professionals in telecommunication, IT, Regulatory in addressing the network constraints in spectrum refarming.

Moreover, the responses affirm that spectrum refarming is seen as a practical solution to improve 4G performance and that it would increase investment in mobile broadband infrastructure.

Limited device compatibility, license restriction and high regulatory fees are barriers to implementation of spectrum refarming requires the intervention of regulators in supporting the process through policy enforcement, cost reduction and financial incentives.

In addition, the results from survey participation indicates that improved 4G coverage will positively affect economic, social sectors with strong support for its impact on online education, business growth and digital inclusion.

Key Questions from Survey

Q1. How Will Better 4G Coverage Impact Social and Economic Activities in Your Region?

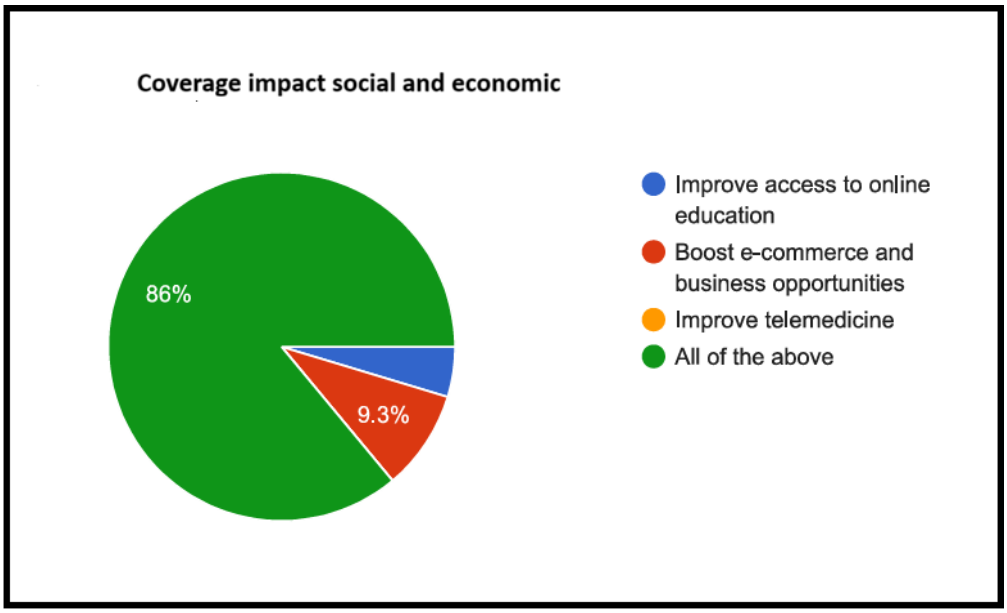


Figure 1. 4G Coverage Impact Social and Economic

https://doi.org/10.21522/TIJAR.2014.13.04.Art027

According to the survey results from Figure 1 above, (86%) of respondents selected all the above showing a strong census that enhanced broadband to have multiple interlinked benefits. (4.7%) of respondents noted that it will bring access to online education in the remote areas and bridging the educational gaps. (9.3%) of respondents pointed out how 4G coverage will boost e-commerce and business opportunities enabling entrepreneurs to adopt digital financial service and reach out to broader markets.

Q2. Which of the Following is a Major Technical Challenge Faced During Spectrum Refarming?

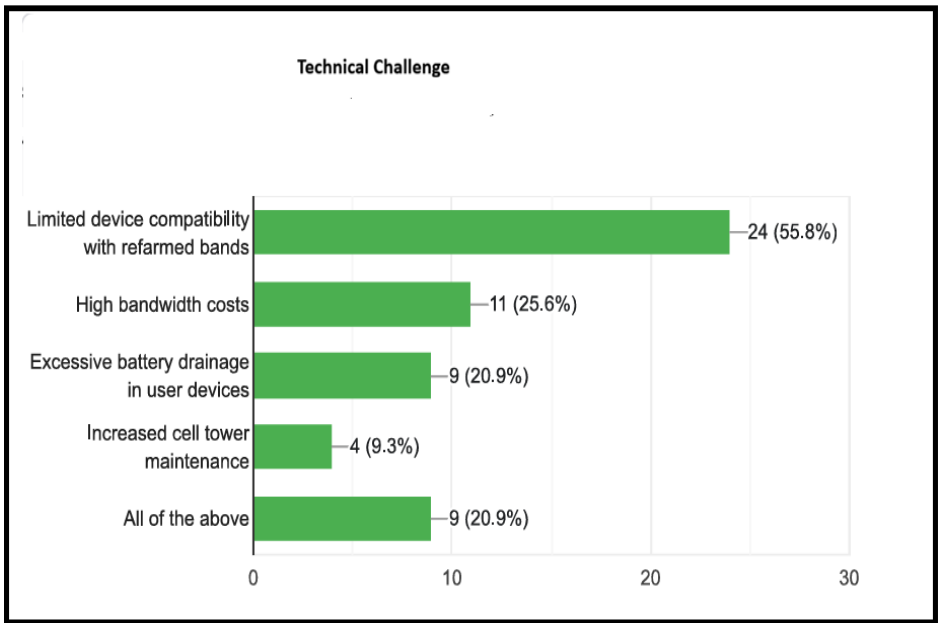


Figure 2. Technical Challenge

From Figure 2, responses from 43 participants were received as the major technical challenges faced during spectrum refarming. The key issues identified represent (55.8%) which was related to the limited device compatibility with refarming bands. The challenge becomes critical because following spectrum refarming data traffic volume is likely to improve significantly. This improvement depends on considering device compatibility as a priority at early planning stage, which enables users to purchase handsets that support the newly deployed frequency bands. Also, high bandwidth cost pose threat to operators in securing required spectrum for deployment.

Q3. What Role Should Government Play in Supporting Spectrum Refarming?

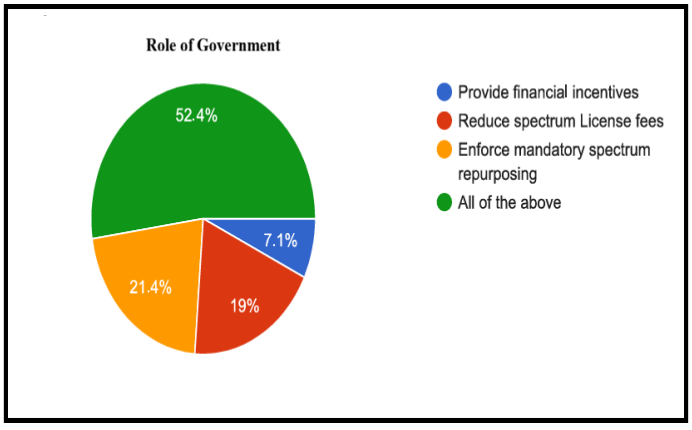


Figure 3. Role of Government

From Figure 3, survey results indicate that the function of government is considered as pivotal in processing successful spectrum refarming. A (52.4%) of respondents selected All of the above suggesting that a complex approach involving both regulatory and financial strategies is most effective. Moreover, (21.4%) of the participants suggest the government to enforce mandatory spectrum reallocation policies ensuring the underutilized spectrum band will be reassigned for efficient use of 4G or 5G. (7.1%) point to the significance of financial incentives to encourage infrastructure upgrades and adoption of new technologies.

Spectrum Refarming and Feasibility Analysis – Summary

The spectrum analysis of AirtelTigo's GSM frequency holdings demonstrates that the GSM 1800 band offers the most practical and technically viable opportunity for LTE refarming. While the GSM 900 allocation comprises approximately 9.8 MHz across PGSM and EGSM blocks, its fragmentation prevents the creation of a contiguous 5 MHz channel necessary for LTE deployment, thereby excluding it as a feasible option. In contrast, AirtelTigo's GSM 1800 allocation includes 15 MHz of contiguous spectrum (ARFCNs 512–586), from which a 5 MHz LTE carrier can be cleanly carved without compromising legacy 2G signaling requirements. A structured plan proposes reallocating ARFCNs 540–564 for LTE, with adjacent guard bands ensuring protection against interference, while residual channels continue to support GSM services.

This carving strategy demonstrates compliance with LTE bandwidth specifications (3GPP TS 36.104) and adheres to global refarming best practices [1], ensuring both spectral efficiency and service continuity. Implementation, however, requires pre-configuration steps such as upgrading base station hardware to multi-standard radios (MSRs) and enabling Multi-RAN software capabilities to allow concurrent GSM and LTE operation. The careful integration of these technical measures transforms theoretical frequency domain planning into a practical LTE deployment framework.

In direct alignment with this study, these findings confirm that GSM 1800 refarming can expand LTE capacity in Ghana, mitigate data throughput limitations, and significantly improve user experience. By systematically reallocating underutilized spectrum, AirtelTigo can modernize its network infrastructure while preserving essential legacy services, providing both immediate QoS gains and a sustainable path toward future mobile evolution.

Vertical Stacked Spectrum Layout

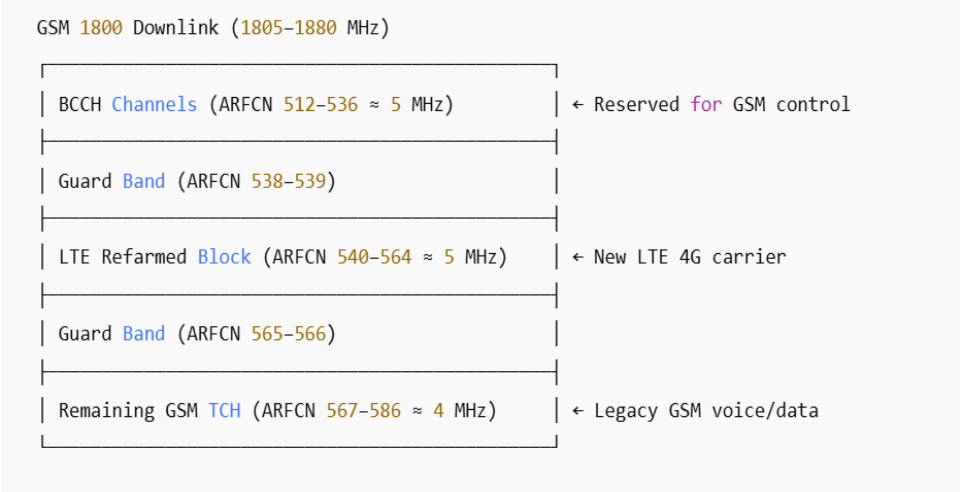


Figure 4. GSM 1800 Spectrum Layout

Figure 4 illustrates the proposed spectrum refarming plan for reallocating a contiguous 5 MHz block within the GSM 1800 MHz band to support LTE deployment while preserving sufficient spectrum resources for legacy GSM services. In summary, this analysis demonstrates a methodical and technically sound approach to refarming 5 MHz of spectrum from the GSM 1800 TCH allocation for LTE deployment. By allocating a total of 29 ARFCNs (5.8 MHz of spectrum), a viable LTE carrier with robust guard banding on both sides is created. The remaining GSM services continue to operate on the BCCH and the unaffected portions of the TCH band, ensuring legacy support. This calculated approach minimizes interference risks and aligns with established spectrum management principles, providing a clear blueprint for network modernization.

Implementation Framework for LTE Deployment in a Refarmed GSM Spectrum

The successful spectral carving of a contiguous 5 MHz block from the GSM 1800 Traffic Channel (TCH) allocation represents a critical first step in the network modernization process. However, this engineering achievement in frequency domain planning must be followed by a comprehensive and multi-disciplinary implementation strategy. Transitioning from a theoretical band plan to an operational LTE carrier requires meticulous execution across technical, operational, and business domains. This narrative outlines the requisite actions and considerations, framing them within a structured implementation framework essential for ensuring service continuity, network integrity, and optimal performance [8].

2G & 3G AirtelTigo Accra Benchmarking & Drive Test DT Findings & Summary

The results show AirtelTigo's clear advantage in 2G performance, with stronger signal strength (–75.6 dBm), superior quality (RxQual 0.07), and the lowest drop call rate (0.15%) among competitors. The only limitation was longer call setup latency (6846.61 ms), suggesting occasional signaling congestion. In 3G, MTN achieved slightly better coverage strength (RSCP –71.48 dBm), but AirtelTigo excelled in signal quality (Ec/Io –11.53 dB), call reliability (DCR 0.27%), and the fastest call setup times. However, AirtelTigo lagged significantly in data throughput, with downlink speeds (7373.89 kbps) far behind MTN (23997.52 kbps), and its voice quality (MOS 3.32) ranked lowest, highlighting areas for improvement. Collectively, these findings indicate AirtelTigo's reliability strengths but also its limitations in capacity intensive services, making spectrum refarming a critical enabler for addressing throughput challenges.

The drive test analyses revealed that all three sites—Accra Mall, 3-Junction, and West Hill Mall exhibited stable 2G and 3G performance, though with variations in signal quality. Accra Mall emerged as the benchmark site, recording an Rxlev of –77.24 dBm and a near-flawless RxQual of 0.01 on 2G, alongside strong 3G RSCP values (–76.15 dBm idle; –73.71 dBm dedicated) and perfect service reliability. 3-Junction displayed slightly weaker but consistent performance, while West Hill Mall showed marginal degradation, with a reduced CSSR of 95.59% indicating occasional accessibility challenges. Collectively, these results establish a pre-refarming baseline, essential for evaluating the impact of spectrum refarming on enhancing 4G capacity and QoS.

https://doi.org/10.21522/TIJAR.2014.13.04.Art027

Recommendations

It is recommended that AirtelTigo leverage spectrum refarming by reallocating underutilized 2G and 3G spectrum to expand LTE capacity, particularly in high-demand areas. AirtelTigo should consolidate its competitive strengths in 2G and 3G coverage stability, low drop call rates, and efficient call setup while strategically addressing weaknesses in data throughput and voice quality. Spectrum refarming provides a direct avenue to achieve this goal: reallocating underutilized 2G and 3G frequencies to expand LTE capacity will improve data rates and user experience, particularly in high-demand urban zones. Secondly, AirtelTigo should complement spectrum refarming with targeted backhaul upgrades and resource optimization strategies to close the throughput gap with MTN. Finally, consistent benchmarking against competitors should be institutionalized to monitor post-refarming improvements and maintain AirtelTigo's competitive positioning.

Future Research Directions

Future research should extend this benchmarking framework to evaluate AirtelTigo's 4G performance following spectrum refarming, with a focus on throughput, latency, and QoS improvements relative to the legacy baselines established here. Comparative studies across urban and rural clusters are also needed to examine whether refarming benefits are equitably distributed across diverse environments. Additionally, research should investigate user-perceived QoS metrics, linking technical KPIs with customer experience to provide a more comprehensive evaluation of network modernization. Finally, given the anticipated transition to 5G, studies should explore how AirtelTigo's refarming strategies can ensure both short-term gains in 4G capacity and long-term readiness for next-generation mobile services.

Conclusion

This thesis has examined the use of spectrum refarming as a strategic approach to enhancing 4G capacity and Quality of Service (QoS) in mobile telephony, with particular emphasis on AirtelTigo's network in Ghana. The analysis demonstrated that the growing demand for broadband services necessitates more efficient utilization of existing spectrum, especially in resource constrained markets where new allocations are limited or costly. Benchmarking results from 2G and 3G drive tests revealed robust legacy performance in terms of coverage and reliability but also highlighted the limitations of spectral occupancy in sustaining next-generation capacity.

The technical feasibility study established that AirtelTigo's GSM 1800 band provides the most practical and contiguous 5 MHz block for LTE deployment. By carefully carving out ARFCNs within this band, while reserving appropriate guard bands, operators can achieve meaningful gains in LTE throughput, coverage efficiency, and QoS without undermining legacy services. Thus, spectrum refarming emerges as both a technically sound and economically efficient pathway for mobile network modernization. In this sense, it is not merely a spectrum reallocation exercise but a strategic enabler of digital transformation, ensuring that operators can sustainably expand 4G services while laying the foundation for eventual 5G transition.

In light of these findings, it is recommended that AirtelTigo adopt spectrum refarming of the GSM 1800 band as a priority modernization strategy. This should be implemented alongside infrastructure upgrades, including the deployment of multi-standard radios (MSRs) and enhanced backhaul capacity, to maximize LTE performance. Furthermore, careful spectrum engineering practices such as guard band allocation and optimized frequency planning must be observed to minimize interference and ensure the continuity of legacy GSM voice services. At the regulatory level,

national telecommunications authorities should establish supportive policies for spectrum reallocation, ensuring equitable access, efficient spectrum use, and alignment with long-term broadband strategies.

Future research could build upon this study in several directions. First, post-deployment evaluations of LTE performance following refarming would provide empirical insights into real world benefits and challenges. Secondly, research into advanced techniques such as spectrum aggregation and dynamic sharing could further enhance spectral efficiency in preparation for 5G. Thirdly, socio-economic analyses of user adoption, affordability, and digital inclusion would complement the technical perspective, ensuring that spectrum refarming strategies translate into meaningful improvements in connectivity and service equity. Together, these recommendations and future research directions underscore the central role of spectrum refarming in advancing 4G capacity and QoS in mobile telephony.

Conflict of Interest

I Albert Neequaye Kotey hereby declared that, there is no conflict of interest regarding this research work.

Ethical Approval

Ethical approval for this study was obtained from the appropriate institutional authority before data collection commenced. Participation in the Google Forms survey was voluntary, and informed consent was obtained electronically from all respondents prior to completing the questionnaire. Participants were assured of anonymity and confidentiality, and no personally identifiable information was collected. The benchmark drive-test data and operational network performance indicators used in this study were obtained with the permission of AirtelTigo Ghana and were used solely for academic research purposes.

Data Availability

The data supporting the findings of this study were obtained from multiple sources. Benchmark drive-test reports and network performance data were provided by AirtelTigo Ghana following formal written approval granted by the Chief Technical Officer for academic research purposes. These proprietary operational data remain confidential and are therefore not publicly available. In addition, the author independently conducted drive-test measurements at Accra Mall, West Hills Mall, and 3 Junction using a third-party drive-test tool to collect field network performance data. Primary data were also collected through a structured Google Forms questionnaire administered to professionals in the telecommunications, information technology, and regulatory sectors. The author-generated drive-test data and anonymized survey data are available from the corresponding author upon reasonable request. Access to AirtelTigo Ghana's proprietary benchmarking reports and operational network performance data remains subject to the prior written approval of AirtelTigo Ghana.

Author Contributions

The author solely conceived the study, designed the methodology, collected and analyzed the data, interpreted the findings, prepared the figures and tables, wrote and reviewed the final manuscript.

Funding

The research received no external funding.

Acknowledgement

I express my profound gratitude to fellow professionals in the Telecom and Information Technology Industry for quick response to the questionnaires, AirtelTigo (AT) for invaluable support when requesting for data, Mr. Daniel Odai for academic counselling, Dr. Samuel Chris Quist (Local Guide) and my dear late wife

(Mrs. Comfort Adjabeng-Ankrah) for the encouragement and patience.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art028

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Three-Dimensional Fragmentation of Health-Care Purchasing and Universal Health Coverage in the Democratic Republic of the Congo

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Cite this article as: Charlie TCHOMBA TULIA. Three-dimensional fragmentation of health-care purchasing and universal health coverage in the Democratic Republic of the Congo. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art028**

Article Type: Review Article

Received: 13.07.2026
Accepted: 01.08.2026
Published: 30.10.2026

Abstract *Progress towards universal health coverage requires available resources to be purchased, allocated, and governed coherently. In the Democratic Republic of the Congo (DRC), analyses of health financing commonly focus on resource scarcity and reliance on out-of-pocket payments, while fragmentation of the purchasing function has received less attention. This analytical review examines fragmentation through three complementary dimensions: financing sources, provider-payment mechanisms, and the institutions that exercise or influence purchasing. A narrative synthesis of health-policy documents, institutional reports, and scientific literature was undertaken and informed by a qualitative comparison of six African country experiences. The analytical framework combines strategic purchasing, neo-institutional theory, and transaction-cost economics. The reviewed literature suggests that compartmentalised financial flows, parallel payment arrangements, and overlapping institutional responsibilities may increase coordination burdens, create unclear incentives for providers, and weaken accountability. The study proposes a three-dimensional model that makes these interactions visible and helps to organise reform options. It concludes that a transition towards more strategic purchasing in the DRC requires clearer purchasing governance, gradual harmonisation of payment arrangements, strengthened information systems, and explicit attention to equity. These priorities should accompany, rather than replace, the necessary expansion of resources for health.*

Keywords *Democratic Republic of the Congo, Fragmentation, Health Financing, Strategic Purchasing, Transaction Costs, Universal Health Coverage.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art028

Introduction

Universal health coverage is a central objective of contemporary health policy. It requires that all people can use the health services they need without experiencing undue financial hardship. Achieving this objective depends not only on the volume of resources mobilised, but also on how these resources are pooled, allocated to providers, and monitored. From this perspective, health-care purchasing is not merely an administrative step: it organises the conversion of financial resources into health services. Kutzin demonstrated that health financing encompasses revenue raising, pooling, and purchasing; the interaction of these functions shapes equity, efficiency, and financial protection [1, 2].

Strategic purchasing refers to active decisions about which services to buy, which providers to contract, which payment methods to use, and which monitoring arrangements to establish [3, 4]. It differs from passive purchasing based on the automatic continuation of historical budgets or on unregulated reimbursement of expenditure. In resource-constrained health systems, strategic purchasing can focus funding on health priorities, support quality of care, and limit inefficient expenditure. However, purchasing instruments do not have identical effects across settings. Their effectiveness depends on coherent rules, implementation capacity, the availability of inputs, and clear institutional responsibilities.

In the DRC, efforts to advance universal health coverage take place in an environment characterised by substantial health needs, a major contribution of households to health-care financing, and the presence of multiple partners and programmes. Research on health financing in sub-Saharan Africa shows that fragmentation extends beyond the multiplicity of financing sources. It may also arise from separate benefit packages, competing payment rules, parallel reporting systems, and overlapping decision-making bodies [5-7].

This article examines fragmentation from the perspective of health-care purchasing. Its contribution is twofold. First, it develops a three-dimensional model that distinguishes fragmentation of sources, mechanisms, and institutions. Second, it interprets the possible effects of this fragmentation through neo-institutional theory and transaction-cost economics. The objective is not to assign causal effects to a single mechanism, but to clarify the plausible pathways through which uncoordinated purchasing arrangements may undermine efficiency, equity, and accountability.

Materials and Methods

Study Design and Analytical Positioning

This study is an analytical thematic review combined with a structured qualitative comparison. It is neither an impact evaluation nor a primary statistical analysis. This design was selected because institutional and scientific documents are available on health financing, health-care purchasing, performance-based financing, financial protection, and governance reforms in the DRC and in other African countries. The analysis seeks to develop a reasoned interpretation of institutional mechanisms rather than to establish a causal effect attributable to a specific intervention.

Documentary Sources and Selection Criteria

The corpus included scientific publications, methodological documents from the World Health Organization, public reports from international institutions, and health-policy documents related to the DRC. Sources were retained when they addressed at least one of the following dimensions: health-financing functions, strategic purchasing, provider-payment methods, performance-based financing programmes, purchasing governance, universal health coverage, financial protection,

or health-service organisation. Purely descriptive texts unrelated to these themes, documents with unverifiable provenance, and sources for which the year or producing institution could not be identified were excluded.

The comparison covered Rwanda, Ghana, Kenya, Burkina Faso, Ethiopia, and Tanzania. These countries were purposively selected because of the diversity of their institutional arrangements, the availability of documented reforms, and their analytical relevance to the DRC. The comparison does not seek to rank countries or to mechanically transfer a model. Rather, it identifies design principles, implementation conditions, and recurrent risks.

Analytical Framework and Synthesis

The main framework is strategic purchasing, which links the content of the benefit package, provider selection, payment mechanisms, contracting arrangements, governance, and performance monitoring [3, 4]. It is complemented by North's neo-institutional theory, according to which formal and informal rules shape behaviour and incentives [8]. Williamson's transaction-cost economics is used to examine the burdens associated with negotiation, verification, information exchange, and contract monitoring [9].

Documents were reviewed using a common analytical grid. Relevant evidence was organised according to the three fragmentation dimensions and four potential effects: coordination costs, divergent incentives, inequalities in coverage, and accountability challenges. A narrative synthesis was then developed using transparency principles for narrative reviews: explicit description of sources, identification of convergences and contradictions, and a clear distinction between documented findings and interpretation [10, 11].

Methodological Limitations

This study has several limitations. Available documents do not cover the same periods, use identical indicator definitions, or provide data of equivalent quality. Literature on payment reforms may also reflect project-specific contexts that do not represent the health system as a whole. The international comparison is qualitative and does not demonstrate that one arrangement is automatically superior in every context. Finally, the use of public secondary data does not allow detailed examination of local practices and informal norms. These limitations mean that the article's proposals should be interpreted as a basis for policy reflection and further research.

Results

A Three-Dimensional Model of Purchasing Fragmentation

Purchasing fragmentation can be understood as the lack of effective alignment among actors, resources, and rules that transform financing into care. It occurs across three related but distinct dimensions. The first concerns sources: public budgets, household payments, insurance, external financing, projects, and earmarked funds. The second concerns mechanisms: operating grants, fee-for-service payment, salaries, capitation, input purchasing, performance-based financing, targeted exemptions, and service contracts. The third concerns institutions: the ministry of health, technical directorates, purchasing agencies, vertical programmes, provincial authorities, development partners, and provider organisations (Table 1).

Multiple sources are not inherently problematic. They become problematic when flows are managed through incompatible rules, when information does not circulate among purchasers, or when providers must comply with contradictory requirements. Likewise, the coexistence of several payment methods may legitimately address different objectives,

including basic financing, quality improvement, equity correction, or coverage of costly services. It becomes inefficient when the payment mix is not designed as a coherent whole.

Table 1. Three-Dimensional Framework for Analysing Purchasing Fragmentation

Dimension	Potential Manifestations	Consequences to Examine
Financing sources	Public budgets, external projects, out-of-pocket payments, insurance schemes, and earmarked funds managed separately.	Limited pooling; incomplete visibility of resources; dispersed spending priorities.
Purchasing mechanisms	Salaries, historical budgets, fee-for-service payments, conditional grants, input purchasing, and parallel exemptions.	Divergent provider signals; administrative complexity; risk of over- or under-incentivisation.
Institutions	Responsibilities shared among regulators, purchasers, vertical programmes, provincial levels, and partners.	Diffuse accountability; slow decisions; overlapping controls; coordination challenges.

Source: *Author's Development Based on [1-4, 8, 9].*

Fragmentation of Sources: Multiple Resources and Limited Visibility

Health systems in low- and middle-income countries commonly rely on a combination of tax revenue, out-of-pocket payments, insurance contributions, and external assistance. This combination can support service delivery when it is coordinated, predictable, and guided by shared rules. Conversely, it may lead to de facto segmentation when each source finances a different package, imposes separate procedures, or prioritises specific geographical areas and population groups. Literature on financing fragmentation indicates that programme-specific funds can facilitate rapid progress in particular areas, but may also reinforce silos when they are not integrated into national planning and purchasing arrangements [5-7, 12].

In the Congolese context, the issue is therefore not solely the overall level of resources. It also concerns the system's ability to identify available financing, align it with health needs, and prevent one stream from substituting for another. Out-of-pocket payments are especially important because they are not an institutional strategic-purchasing mechanism: they depend on the patient's immediate ability to pay. When they finance a substantial share of services, they may restrict access, delay care seeking, and weaken risk pooling [13, 14].

Fragmentation of Mechanisms: The Need for Coherent Incentives

Provider-payment methods influence provider behaviour. A salary may secure income and facilitate staff presence, but it does not necessarily create a direct incentive to increase activity or improve particular quality processes. Fee-for-service payment can stimulate service provision but may also encourage unnecessary volumes when safeguards are absent. Capitation creates incentives for cost control but requires adjustment for health needs and referral arrangements to avoid risk selection. Performance-based financing can make priority objectives more visible, but its effects depend on the availability of inputs, the quality of verification, and compatibility with other financing sources [15-17] (Table 2).

The relevant question is therefore not whether to choose a single mechanism, but how

to define an explicit payment mix. A mixed architecture may distinguish financing for fixed costs, purchasing of priority services, protection of vulnerable people, and remuneration for quality improvements. Without coordination rules, providers may be encouraged to prioritise the most visible activities, those that are easiest to report, or those that are best remunerated, at the expense of equally essential but insufficiently funded services. Administrative workload can also become excessive when each mechanism requires separate registers, controls, and reports.

Table 2. Main Provider-Payment Mechanisms and Risks of Fragmentation

Mechanism	**Potential Purpose**	**Risk When Implemented in Isolation**
Operating budget or global grant	Support fixed costs, service continuity, and readiness of the supply side.	Allocation may remain weakly responsive to needs or quality when based strictly on historical levels.
Salary	Provide predictable remuneration for staff.	Weak relationship with effective availability, quality, or activity in the absence of supervision.
Fee-for-service payment	Remunerate services that are actually delivered.	Incentive to increase service volumes and persistence of financial barriers for households.
Capitation	Finance an enrolled population and encourage prevention.	Under-provision or risk selection if the payment is not adjusted and monitored.
Performance-based financing	Emphasise selected services or verifiable results.	Focus on remunerated indicators; verification costs; dependence on external inputs.
Equity funds or exemptions	Reduce financial barriers for vulnerable groups.	Inaccurate targeting, delayed reimbursement, or financial fragility of health facilities.

Source: *Author's Synthesis Based on [3, 4, 15-17].*

Institutional Fragmentation: Separation of Roles and Accountability

Purchasing governance requires, at least functionally, a distinction among regulatory, financing, purchasing, provision, and oversight responsibilities. In practice, these functions may be performed by several entities, provided that their mandates are clear and coordination rules are operational. Conversely, when roles overlap without an explicit decision-making mechanism, accountability becomes diffuse. It becomes difficult to identify who is responsible for defining the benefit package, selecting providers, ensuring contract quality, or settling payments.

Institutional theory helps interpret this problem beyond formal organisational charts. A reform may introduce contracts, indicators, or a new structure, but its operation depends on pre-existing work practices, authority relationships, and norms of exchange. The central issue is the fit between new rules and available administrative capacities. When an arrangement demands more rapid or more detailed information than health facilities can produce, it may generate weak data or excessive workload without commensurate benefit [8, 18].

Plausible Mechanisms of Inefficiency

The synthesis identifies three interpretive mechanisms. The first is dilution. When limited resources are distributed across numerous channels, an increasing share may be absorbed by the management of agreements, accounts, controls, and reports. The multiplication of such operations corresponds to transaction costs in Williamson's sense. This does not mean that all verification is unnecessary: control is essential for quality and integrity. The problem arises when verification is redundant, poorly targeted, or disproportionate to risk.

The second mechanism is contradictory incentives. Multiple purchasers may communicate different and sometimes competing priorities to the same providers. One programme may reward completion of an indicator, another the availability of a commodity, while the health facility still relies on out-of-pocket payments to cover day-to-day operating costs. In the absence of prioritisation, providers may adapt locally in rational ways that are not necessarily consistent with public-health objectives. This issue is particularly relevant for integrated services that require staff, medicines, reliable data, and continuity of care at the same time.

The third mechanism is an accountability gap. When several institutions finance, monitor, and direct activities without a shared decision framework, no actor fully bears responsibility for the overall result. Service users may then have few clear avenues for reporting failures, while local authorities may have to respond to multiple requirements. The consequence is not necessarily an absence of control, but fragmented control focused on compliance with individual project rules rather than on continuity and equity of care.

Comparative Lessons from African Countries

The countries included in the comparison (Table 3) are not models to be copied without adaptation. They nevertheless offer useful lessons. Rwanda is frequently discussed in the literature because of the progressive alignment of community-based insurance, provider financing, and monitoring arrangements. The principal lesson is not the adoption of a particular instrument, but the coherence built among basic financing, governance, and information improvement [16, 19].

Ghana illustrates the importance of a national purchaser able to define reimbursement rules and a benefits package, while also facing sustainability challenges and payment delays. Kenya shows that decentralisation can bring decision-making closer to local needs, but requires management capacity, predictable transfer rules, and strong coordination across levels of government. Burkina Faso has contributed to reflection on performance-based financing by showing that incentives cannot replace the availability of inputs or equity measures. Ethiopia and Tanzania further show that expanding financial protection is a gradual process that depends on strengthening service delivery, local governance, and public trust [6, 13, 17].

Table 3. Qualitative Comparison of African Experiences in Healthcare Purchasing and Financing

Country	Experience Examined	Cautious Lesson for the DRC
Rwanda	Progressive alignment of insurance mechanisms, provider financing, and monitoring.	Seek coherence among the purchaser, information systems, basic financing, and gradual supply-side improvement.
Ghana	Role of a national insurance scheme in financing and purchasing services.	An organised purchaser requires sustainable financing rules and predictable payments.

Kenya	Decentralisation and transfer of responsibilities to subnational levels.	Decentralisation requires local capacity, clear mandates, and intergovernmental coordination.
Burkina Faso	Performance-based financing experiences and equity measures.	Incentives must be aligned with inputs, supervision, and protection for vulnerable populations.
Ethiopia	Gradual development of financial-protection mechanisms and primary health care.	Supply-side strengthening and institutional trust condition the expansion of coverage.
Tanzania	Multiple financing arrangements and efforts to increase pooling.	Gradual consolidation of arrangements is preferable to layering poorly coordinated schemes.

Source: *Author's Synthesis Based on [5, 7, 16, 17, 19].*

Discussion

Conceptual Contribution: Making Purchasing Fragmentation Visible

The central contribution of this study is to move the analysis of fragmentation beyond the diversity of financing sources alone. Three-dimensional fragmentation helps explain why a reform limited to payment methods or resource mobilisation may produce inconsistent results. A payment arrangement can be technically well designed yet fail to improve services if it is introduced where inputs are unavailable, responsibilities are ambiguous, or the information required for verification is unreliable.

The model does not claim that all plurality is harmful. Health systems often use several instruments because they pursue several objectives. Financing staff availability, purchasing essential medicines, incentivising selected activities, protecting households financially, and responding to emergencies do not necessarily require the same mechanism. The key policy question is one of architecture: which functions should be integrated, which may remain distinct, and which mechanisms can ensure coordination among them?

Implications for Strategic Purchasing in the DRC

A first implication is the need for a national mapping of purchasing flows and rules. For every financing source, the map should identify the manager, the relevant benefit package, eligible providers, payment methods, reporting requirements, and verification arrangements. It should be updated regularly and shared across national, provincial, and local levels. Without such visibility, harmonisation remains declaratory.

A second implication is the development of a national framework for mixed provider payments. The framework should specify the function of each instrument and prevent multiple purchasers from financing the same activities under incompatible rules. A predictable grant could support unavoidable facility costs. Payments linked to quality or performance could be directed to a limited number of genuinely measurable priority indicators. Equity arrangements should protect groups for whom out-of-pocket payments are a major barrier. The choice of parameters should be preceded by feasibility assessments, analyses of administrative costs, and consideration of distributional effects.

A third implication concerns governance. A more coherent purchasing function does not necessarily require the immediate creation of an entirely new institution. It first requires clearly defined mandates, transparent decision-making arrangements, conflict-of-interest safeguards, and consultation mechanisms involving provinces, providers, and service-user

representatives. In the longer term, the option of a public purchaser with functional autonomy may be considered, provided that its financing, oversight, and legitimacy are clearly established.

A fourth implication relates to information systems. Digitalisation can reduce delays and facilitate data consolidation, but it should not create an additional reporting channel. Investments should promote interoperability, local use of data for decision-making, protection of sensitive information, and verification that is proportionate to risk. The guiding principle is straightforward: information requested from health facilities should have a demonstrable use for service improvement or accountability.

Future Research

The proposals advanced here require empirical testing. Future work could develop a quantitative inventory of financing sources and calculate concentration indicators using explicitly defined categories. It could also measure transaction costs by distinguishing expenditure on contracting, oversight, information management, and coordination. Case studies in health zones could examine how providers arbitrate among multiple purchasing arrangements. Finally, quasi-experimental evaluations or longitudinal analyses would be needed to estimate the effects of specific reforms on service utilisation, quality of care, and financial protection. Comparable institutional questions have also been documented in other regions, including Latin America and the Caribbean [20].

Conclusion

Fragmentation of health-care purchasing is a structural issue for progress towards universal health coverage in the DRC. The analysis shows that fragmentation should be examined simultaneously across financing sources, payment mechanisms, and institutions. Coordination difficulties, divergent incentives, and diffuse responsibilities are plausible mechanisms through which poorly aligned arrangements may limit efficiency and equity. The appropriate response is not the immediate uniformisation of all financing, but progressive consolidation: making flows visible, defining the role of each instrument, harmonising data requirements, strengthening accountability, and protecting households from out-of-pocket payments. These directions should be accompanied by sustained investments in service delivery and by rigorous empirical evaluations adapted to the Congolese context.

Conflict of Interest

The author declares no conflict of interest. The sources used in this review consist of scientific publications, institutional documents, and publicly accessible secondary data.

Acknowledgements

The author thanks the institutions and authors whose publications and documents made this analytical review possible.

Ethical Approval

This study relied exclusively on the analysis of publicly accessible documents and aggregated secondary data. It involved neither participant recruitment nor the use of identifiable individual data. Individual ethical approval was not required for the analysis described, subject to applicable institutional requirements.

Author Contributions

Charlie TCHOMBA TULIA: conceptualization, methodology, data curation, formal analysis, investigation, original draft preparation, review and editing, and project administration.

Funding

This research was self-funded.

Data Availability

The documents and data examined are derived from public secondary sources, including scientific publications and institutional documents cited in the reference list. Requests for any non-public administrative data should be directed to the relevant data-holding institution in accordance with its access procedures.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art029

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Understanding Covid-19 Vaccine Hesitancy in Africa: A Systematic Review of Sociocultural Beliefs, Trust in Health Systems, and Misinformation Dynamic

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Cite this article as: Egbe Derick Agbor, Eyong Manyiyong Queenta, Fietsop Ernestine Nkemta, Frida Bessem Taku Bate, Eyong Bessemeyong Velda. Understanding Covid-19 Vaccine Hesitancy in Africa: A Systematic Review of Sociocultural Beliefs, Trust in Health Systems, and Misinformation Dynamic.Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art029**

Received: 27.05.2026

Accepted: 08.10.2026

Published: 30.10.2026

Article Type: Review Article

Abstract *COVID-19 vaccine hesitancy became a major challenge affecting vaccination efforts across African countries during the COVID-19 pandemic. This systematic review examined sociocultural beliefs, trust in health systems, and misinformation dynamics influencing vaccine hesitancy across Africa. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Electronic databases including PubMed, Scopus, Web of Science, Google Scholar, African Journals Online (AJOL), and ScienceDirect were searched for studies published between 2020 and 2026. Additional reports were obtained from the World Health Organization (WHO), United Nations Children's Fund (UNICEF), and Africa Centres for Disease Control and Prevention (Africa CDC). Studies addressing COVID-19 vaccine hesitancy among African populations were included. A total of 286 records were identified, with 38 studies meeting the inclusion criteria after screening and eligibility assessment. The review revealed that vaccine hesitancy across Africa was driven by multiple interconnected factors including misinformation spread through social media, mistrust in governments and healthcare systems, sociocultural and religious beliefs, fear of vaccine side effects, and concerns regarding vaccine safety. Misconceptions related to infertility, hidden political agendas, and harmful effects of vaccines were frequently reported. Healthcare worker hesitancy, poor public health communication, and socioeconomic inequalities further contributed to low vaccine confidence in several African settings. The review concludes that improving vaccine uptake in Africa requires culturally sensitive communication strategies, strengthened institutional trust, effective misinformation control, and stronger community engagement to improve confidence in future vaccination programs.*

Keywords *Africa, COVID-19 Vaccine Hesitancy, Misinformation, Public Health Communication, Sociocultural Beliefs, Trust in Health Systems, Vaccine Acceptance.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art029

Introduction

Vaccination has remained one of the most successful public health interventions for controlling infectious diseases, reducing mortality, and improving global health outcomes [1]. During the COVID-19 pandemic, the rapid development and deployment of vaccines represented a major scientific and medical achievement aimed at limiting transmission, reducing severe illness, and preventing deaths associated with the disease [2]. Governments, international organizations, and public health institutions promoted vaccination as a central strategy for controlling the pandemic and restoring social and economic stability. Despite these efforts, many countries experienced substantial challenges related to vaccine acceptance and uptake, particularly within low- and middle-income settings [3]. In several regions, low vaccination coverage weakened public health responses and slowed progress toward population immunity.

COVID-19 vaccine hesitancy quickly became a major global public health concern during the pandemic period. Vaccine hesitancy refers to delay in acceptance or refusal of vaccines despite the availability of vaccination services [3]. Even before the emergence of COVID-19, the World Health Organization had identified vaccine hesitancy among the major threats affecting global health because of its growing influence on immunization programs and disease prevention efforts [4]. During the pandemic, fear, uncertainty, misinformation, and mistrust surrounding newly developed vaccines further intensified hesitancy across different populations [5].

Globally, vaccine-related decisions were influenced by a combination of social, cultural, political, and institutional factors [6, 7]. Concerns regarding vaccine safety, fear of side effects, distrust in governments and pharmaceutical industries, and exposure to misinformation contributed significantly to reduced vaccine confidence in many countries. Social media platforms such as Facebook, WhatsApp, YouTube, and Twitter became major channels through which false information and conspiracy narratives circulated rapidly [8]. Claims suggesting that COVID-19 vaccines could cause infertility, alter human DNA, implant microchips, or serve hidden political agendas generated fear and confusion within several communities worldwide [9].

In Africa, vaccine hesitancy became particularly concerning despite continuous vaccination campaigns and efforts to improve public awareness [10]. Historical distrust in governments, previous experiences with healthcare systems, sociocultural beliefs, and limited confidence in public institutions influenced vaccine attitudes across several African populations [11]. In some settings, communities questioned the rapid development of COVID-19 vaccines and expressed uncertainty regarding vaccine safety, transparency, and possible long-term effects [12].

To improve vaccine uptake, several African countries implemented public sensitization campaigns, community mobilization strategies, and engagement of healthcare workers, religious leaders, and community influencers [13]. Trust in healthcare professionals was frequently associated with improved vaccine acceptance, whereas mistrust in political institutions and public authorities often contributed to resistance toward vaccination programs [14]. However, vaccine hesitancy persisted across many African settings despite these interventions [15]. This persistence suggests that hesitancy was not simply a matter of inadequate vaccine supply or lack of information but was also linked to broader social realities, institutional trust, communication dynamics, and cultural perceptions surrounding health and vaccination.

Although many studies have explored COVID-19 vaccine hesitancy within specific

African countries and populations, the available evidence remains fragmented. Some studies focused mainly on misinformation and social media influence, while others examined sociocultural beliefs, vaccine safety concerns, or trust-related factors independently. Limited synthesized evidence exists bringing together these interconnected determinants across African populations. Understanding how these factors interact is important for strengthening public health communication, improving vaccine confidence, guiding policy decisions, and supporting future vaccination programs across the continent.

This systematic review was therefore conducted to synthesize available evidence on sociocultural beliefs, trust in health systems, and misinformation dynamics influencing COVID-19 vaccine hesitancy across Africa. The review provides an integrated examination of cultural, institutional, and communication-related factors shaping vaccine attitudes across multiple African settings rather than focusing on isolated determinants or single-country experiences. The findings may contribute to strengthening public health communication strategies, improving vaccine confidence, and supporting future immunization programs within African populations.

Materials and Methods

This study was conducted as a systematic review aimed at synthesizing evidence on sociocultural beliefs, trust in health systems, and misinformation dynamics influencing COVID-19 vaccine hesitancy across Africa. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure a structured and transparent review process [16].

A comprehensive literature search was conducted between January and April 2026 using electronic databases including PubMed, Scopus, Web of Science, Google Scholar, African Journals Online (AJOL), and ScienceDirect. Additional reports and policy documents were retrieved from the World Health Organization (WHO), United Nations Children's Fund (UNICEF), Africa Centres for Disease Control and Prevention (Africa CDC), and other international public health organizations involved in immunization programs in Africa [17-19].

The search strategy combined keywords and Medical Subject Headings (MeSH) related to vaccine hesitancy and Africa. The main search terms included "vaccine hesitancy," "vaccine acceptance," "COVID-19 vaccine hesitancy," "misinformation," "social media," "trust in health systems," "sociocultural beliefs," and "Africa." Boolean operators such as AND and OR were used to refine the search and improve retrieval of relevant studies.

Studies were included if they focused on COVID-19 vaccine hesitancy within African populations and addressed sociocultural beliefs, misinformation, trust-related factors, or health system influences affecting vaccine uptake. Quantitative studies, qualitative studies, mixed-method studies, systematic reviews, and national survey reports published between 2020 and 2026 in English or French were considered eligible for inclusion. Editorials, conference abstracts, opinion papers, duplicate studies, and articles with inaccessible full texts were excluded from the review.

Titles and abstracts of retrieved studies were screened for relevance before full-text review. Relevant information extracted from selected studies included author, year of publication, country, study design, study population, key determinants of vaccine hesitancy, and major findings. The findings were synthesized narratively and organized into thematic areas including sociocultural beliefs, trust in health systems, misinformation dynamics, perceived vaccine safety concerns, healthcare worker attitudes, and socioeconomic factors influencing COVID-19 vaccine hesitancy across Africa.

https://doi.org/10.21522/TIJAR.2014.13.04.Art029

Results

The literature search conducted across PubMed, Scopus, Web of Science, Google Scholar, African Journals Online (AJOL), and ScienceDirect identified 286 records related to COVID-19 vaccine hesitancy in Africa. Additional articles and reports were obtained from the World Health Organization (WHO), Africa Centres for Disease Control and Prevention (Africa CDC), and reference lists of relevant studies. After removal of 48 duplicate records, 238 articles remained for title and abstract screening.

During the screening stage, 161 articles were excluded because they did not focus on COVID-19 vaccine hesitancy within African populations, addressed unrelated public health topics, or lacked relevance to the objectives of the review. Seventy-seven full-text articles were subsequently assessed for eligibility. Following full-text review, 39 studies were excluded because they did not sufficiently address sociocultural beliefs, misinformation, trust-related factors, or determinants of vaccine hesitancy in Africa. Editorials, commentaries, conference abstracts, duplicate publications, and studies with inaccessible full texts were also excluded. Finally, 38 studies met the inclusion criteria and were retained for the review. The study selection process is summarized in Figure 1.

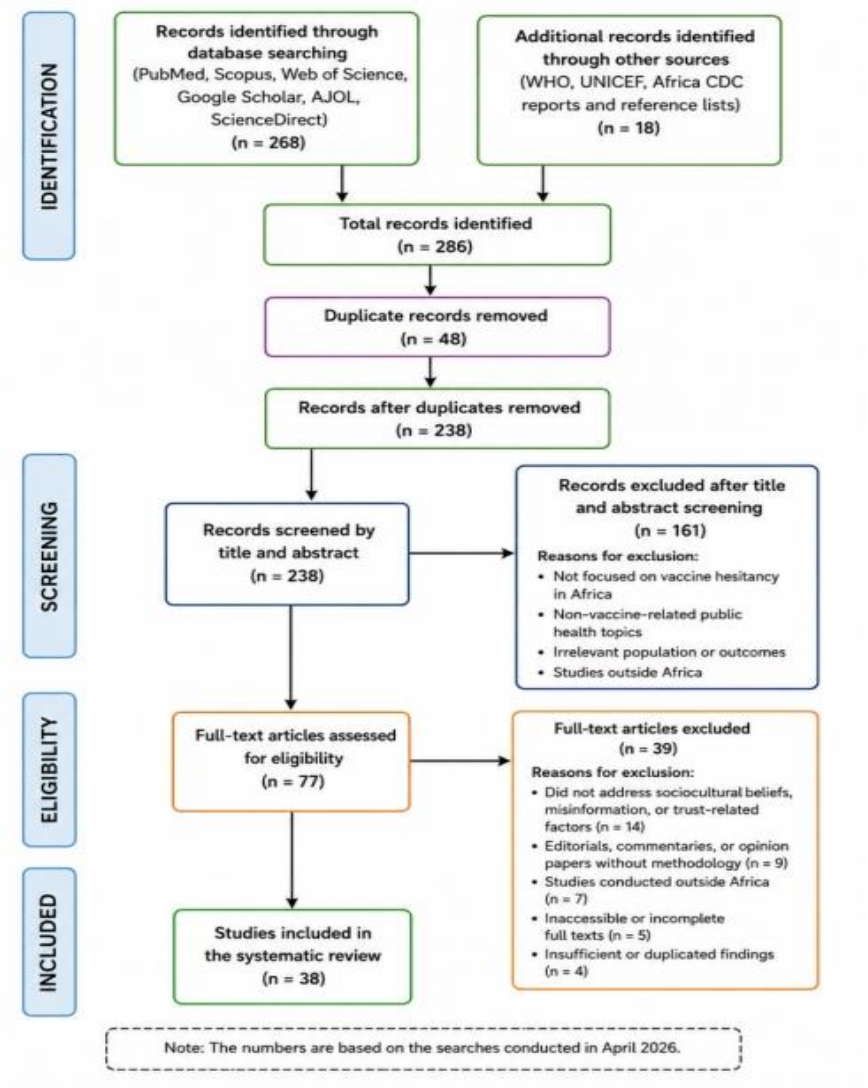


Figure 1. Flow Diagram Showing the Study Selection Process for the Systematic Review on Vaccine Hesitancy in Africa

The included studies were published between 2020 and 2025 and were conducted across several African countries including Cameroon, Nigeria, Ghana, Ethiopia, Uganda, South Africa, Zimbabwe, Tanzania, Egypt, and the Democratic Republic of Congo. Multi-country African studies and systematic reviews were also represented [20-25]. Most of the studies employed cross-sectional study designs, while others consisted of qualitative studies, mixed-method studies, systematic reviews, scoping reviews, and meta-analyses. The majority of the studies focused on COVID-19 vaccine acceptance, vaccine hesitancy, and associated determinants among adults, healthcare workers, university students, and community populations. The characteristics of the included studies are presented in Table 1.

Table 1. Characteristics of Studies Included in the Systematic Review on COVID-19 Vaccine Hesitancy in Africa

No.	Author(s)	Year	Country/Setting	Study Design	Study Population	Main Findings
1	Dinga et al.	2021	Cameroon	Cross-sectional	Adults	High vaccine hesitancy linked to trust and media influence
2	Dinga et al.	2022	Cameroon	Cross-sectional comparison	Adults	Traditional remedies and mistrust influenced hesitancy
3	Cheuyem et al.	2025	Cameroon	Systematic review/meta-analysis	General population	Reported pooled vaccine hesitancy and acceptance rates
4	Solís Arce et al.	2021	African LMICs	Multi-country survey	Adults	Trust in healthcare workers improved vaccine acceptance
5	Bono et al.	2021	Multi-country Africa	International survey	General population	Safety concerns and trust affected uptake
6	Acheampong et al.	2021	Ghana	Cross-sectional	Adults	Vaccine safety concerns reduced acceptance
7	Echoru et al.	2021	Uganda	Cross-sectional	Adults	Fear of adverse effects contributed to hesitancy
8	Wake	2021	Ethiopia	Cross-sectional	Adults	Social media misinformation influenced attitudes
9	Cooper et al.	2021	South Africa	Review	General population	Historical distrust influenced vaccine perceptions
10	Afolabi & Ilesanmi	2021	Africa	Commentary / Review	General population	Discussed vaccine hesitancy in Africa
11	Akrong et al.	2024	Ghana	Systematic review	General population	Synthesized hesitancy evidence in Ghana

12	Abubakari et al.	2023	Five African countries	Multi-country survey	Adults	Assessed vaccine readiness and hesitancy
13	Ackah et al.	2022	Africa	Scoping review	General population	Identified contextual determinants of hesitancy
14	Alie et al.	2024	East Africa	Systematic review/meta-analysis	Adults	Reported pooled vaccine hesitancy estimates
15	Unfried et al.	2024	Sub-Saharan Africa	Quantitative analysis	Adults	Trust in institutions predicted acceptance
16	Al-Mustapha et al.	2022	Nigeria	National survey	Adults	Assessed national vaccine hesitancy patterns
17	Njoga et al.	2022	Nigeria	Cross-sectional	Adults	Identified determinants of vaccine hesitancy
18	Olawade et al.	2022	Nigeria	Cross-sectional	Youths and students	Misinformation influenced vaccine attitudes
19	Omale et al.	2022	Nigeria	Cross-sectional	Adults and healthcare workers	Poor confidence affected vaccine acceptance
20	Sato	2023	Nigeria	National survey	Adults	Examined changing hesitancy trends
21	Erega et al.	2022	Ethiopia	Cross-sectional	Adults	Fear and myths influenced hesitancy
22	Mose et al.	2022	Ethiopia	Systematic review/meta-analysis	General population	Synthesized vaccine acceptance determinants
23	Sahile et al.	2022	Ethiopia	Cross-sectional	College students	Assessed predictors of vaccine acceptance
24	Tilahun et al.	2023	Ethiopia	Cross-sectional	University students	Identified barriers to vaccine uptake
25	Anteneh et al.	2024	Ethiopia	Latent class analysis	Adults	Classified patterns of vaccine hesitancy
26	Okai et al.	2022	Ghana	Cross-sectional	Adults	Identified determinants of vaccine acceptance
27	Brackstone et al.	2022	Ghana	Cross-sectional	Adults	Political allegiance influenced hesitancy
28	Lamptey et al.	2021	Ghana	Nationwide survey	Adults	Assessed predictors of vaccine uptake

29	Asumah et al.	2022	Ghana	Cross-sectional	Healthcare professionals	Safety concerns reduced confidence
30	Kabagenyi et al.	2022	Uganda	Population-based survey	Adults	Identified demographic predictors of hesitancy
31	Bongomin et al.	2021	Uganda	Cross-sectional	High-risk populations	Assessed vaccine acceptance
32	Kanyike et al.	2021	Uganda	Cross-sectional	Medical students	Mistrust and fear influenced hesitancy
33	Ditekemena et al.	2021	DR Congo	Cross-sectional	Adults	Assessed vaccine hesitancy and acceptance
34	Nzaji et al.	2020	DR Congo	Cross-sectional	Healthcare workers	Low confidence influenced vaccine acceptance
35	Moola et al.	2021	South Africa	Qualitative	Community members	Fear and mistrust shaped perceptions
36	Sewpaul et al.	2023	South Africa	Cross-sectional	Adults	Socioeconomic factors influenced hesitancy
37	Adebisi et al.	2021	Nigeria	Review	General population	Misinformation influenced vaccine attitudes
38	Osuagwu et al.	2021	Sub-Saharan Africa	Multi-country survey	Adults	Distrust and misinformation contributed to hesitancy

Sociocultural and Religious Beliefs Influencing Vaccine Hesitancy

Sociocultural and religious beliefs emerged as important determinants of COVID-19 vaccine hesitancy across several African settings [20-33]. In Cameroon and Nigeria, some participants associated COVID-19 vaccines with infertility, hidden political agendas, and harmful intentions toward African populations [20, 21, 29, 30]. Preference for traditional remedies and herbal medicine over vaccination was also reported in some communities [20, 25]. Studies conducted in Ghana and Ethiopia further showed that religious beliefs and community perceptions influenced attitudes toward vaccination [23, 24, 31-33]. In Uganda, acceptance of vaccination was additionally shaped by social beliefs, fear, and misconceptions surrounding vaccine safety and effectiveness [26].

Trust in Governments and Health Systems

Several studies identified mistrust in governments, healthcare systems, and pharmaceutical institutions as major barriers affecting vaccine uptake across African populations [22, 25, 27, 28, 34-38]. In Cameroon, South Africa, Nigeria, and the

Democratic Republic of Congo, low confidence in government communication and public health authorities contributed significantly to vaccine hesitancy [20, 27, 29, 38]. Multi-country African studies further demonstrated that trust in healthcare workers positively influenced vaccine acceptance and confidence [22, 34]. However, weak public communication, concerns regarding transparency, and distrust in political systems negatively affected public willingness to receive COVID-19 vaccines in several countries [35-37].

Misinformation and Social Media Influence

Misinformation circulating through social media platforms was consistently identified as an important contributor to vaccine hesitancy [22, 29, 33, 39]. WhatsApp, Facebook, YouTube, and other digital platforms were frequently reported as major channels for the spread of false information regarding COVID-19 vaccines. Common misconceptions included beliefs that vaccines could alter human DNA, cause infertility, implant microchips, or lead to severe long-term health complications [29, 33].

Perceived Vaccine Safety Concerns

Fear of side effects and concerns regarding vaccine safety were among the most recurrent barriers identified across the reviewed studies [22-24, 32, 40]. Participants expressed fears related to blood clotting, infertility, severe illness, death, and unknown future health effects associated with COVID-19 vaccines [22, 32]. Healthcare workers in Ghana, Tanzania, Egypt, and the Democratic Republic of Congo also reported uncertainty regarding vaccine safety and effectiveness. Studies have indicated that the rapid development and emergency approval of COVID-19 vaccines contributed to public skepticism and uncertainty [22].

Healthcare Worker and Health System Factors

Healthcare worker attitudes and broader health system limitations also influenced vaccine hesitancy across African settings [22, 25, 40]. Weak healthcare infrastructure, inconsistent public health communication, limited community engagement, and inadequate risk communication strategies were also identified as barriers affecting vaccine acceptance [25, 40]. At the same time, healthcare workers remained important sources of trusted health information in several communities [22, 34].

Socioeconomic and Demographic Factors

Several studies reported that socioeconomic and demographic characteristics influenced vaccine hesitancy patterns across African populations [39, 40]. Younger individuals, unemployed persons, populations with lower educational levels, and some rural communities were more likely to express vaccine hesitancy in several settings [26, 27, 30, 31]. However, some studies also showed that vaccine hesitancy was present among educated populations due to misinformation exposure and mistrust in institutions [4, 33]. Socioeconomic inequalities, poor access to reliable health information, and limited health literacy were further associated with reduced vaccine confidence across several African countries [27, 35-37].

The findings from the reviewed studies demonstrate that COVID-19 vaccine hesitancy in Africa is influenced by complex interactions between sociocultural beliefs, misinformation dynamics, trust-related factors, perceived vaccine safety concerns, healthcare system limitations, and socioeconomic realities.

Discussion

COVID-19 vaccine hesitancy became one of the most difficult barriers affecting vaccination efforts across African countries during the pandemic period. This review shows that hesitancy was not driven by a single factor but rather by the interaction of sociocultural beliefs, misinformation, distrust in institutions, political experiences, and health system limitations. Across many African settings, public perceptions surrounding COVID-19 vaccines were strongly shaped by historical experiences, local realities, and community narratives. Fear of side effects, distrust in governments, misinformation spread through social media, and uncertainty surrounding vaccine safety repeatedly appeared across the reviewed studies [20-22, 25, 29, 34].

In many African communities, health decisions are closely connected to cultural beliefs, religious influence, and trust within social networks. This was evident in studies conducted in Cameroon, Nigeria, Ghana, and Ethiopia where misconceptions related to infertility, population control, hidden political motives, and harmful foreign intentions affected public confidence in COVID-19 vaccines [20, 21, 23, 24, 29-33]. In some settings, traditional medicine and herbal remedies were perceived as safer and more familiar alternatives compared to newly developed vaccines [20, 25]. Such findings reflect the importance of understanding local belief systems when implementing public health interventions. Vaccination campaigns that fail to consider cultural realities may struggle to achieve community acceptance regardless of vaccine availability.

The findings also reveal important differences between African countries and populations. In Cameroon and Nigeria, mistrust was frequently linked to political narratives, rumors, and suspicion toward foreign-supported health interventions [20, 21, 29, 30]. In contrast, studies from South Africa highlighted how historical inequalities, political dissatisfaction, and previous experiences with healthcare systems shaped vaccine attitudes [27]. These differences demonstrate that vaccine hesitancy in Africa cannot be approached as a uniform continental problem. Social experiences, political environments, and health system histories vary considerably across countries, influencing how communities interpret public health messages.

Trust in governments and healthcare systems emerged as another major issue influencing vaccine uptake [22, 25, 27, 28, 34-38]. Individuals who lacked confidence in governments or public health institutions were generally more hesitant to accept vaccination. In several settings, communities questioned the transparency of information provided by health authorities and expressed doubts regarding the intentions behind vaccination campaigns [20, 38]. Low institutional trust appeared particularly important in countries where populations already faced political instability, weak healthcare systems, or poor access to reliable health information.

At the same time, healthcare workers remained among the most trusted sources of health information in many African communities [22, 34]. However, an important contradiction became visible across several studies. While healthcare professionals were expected to promote vaccination, some healthcare workers themselves expressed fear, uncertainty, and hesitancy regarding COVID-19 vaccines. Concerns regarding side effects, insufficient information, and the rapid development of vaccines contributed to hesitation even among trained professionals. This contradiction likely weakened public confidence because communities often depend on healthcare workers for guidance during health emergencies. When healthcare providers themselves express uncertainty, public doubt can increase substantially.

Misinformation played a particularly strong role in shaping vaccine attitudes across the continent [22, 29, 33, 37]. Social media

platforms such as WhatsApp, Facebook, and YouTube became major channels for spreading false claims regarding COVID-19 vaccines. Rumors suggesting that vaccines could alter DNA, cause infertility, implant microchips, or intentionally harm African populations circulated widely during the pandemic [29, 33]. In many settings, misinformation spread more rapidly than official public health communication. This was especially problematic in communities with limited access to verified scientific information or low health literacy levels.

Younger populations and university students appeared especially vulnerable to misinformation exposure through digital platforms. However, hesitancy was not limited to less educated groups alone. Some studies showed that educated populations also expressed mistrust and skepticism toward vaccines [33]. This suggests that vaccine hesitancy is more complex than lack of knowledge alone. Exposure to conflicting information, political distrust, and uncertainty surrounding rapidly evolving scientific guidance also influenced attitudes among educated individuals.

Fear of vaccine side effects remained one of the most consistent concerns across the reviewed studies [22-24, 32, 40]. Participants frequently expressed fears related to infertility, blood clotting, severe illness, disability, and possible long-term health consequences. Similar concerns were reported among healthcare workers in Ghana, Tanzania, Egypt, and the Democratic Republic of Congo. The rapid development and emergency approval of COVID-19 vaccines appeared to increase public uncertainty in several settings. For many communities, the speed of vaccine production created doubts regarding safety, testing processes, and long-term effects.

Weak healthcare infrastructure and poor public communication further complicated vaccination efforts in several African countries [25, 34, 40]. Inconsistent messaging from public health authorities, limited community engagement, and inadequate risk communication reduced confidence in vaccination programs. In some areas, access to accurate information remained limited while rumors and conspiracy theories continued to spread freely. These challenges demonstrate that vaccine hesitancy should not only be viewed as individual refusal but also as a reflection of broader structural weaknesses within health systems and communication structures.

The review also highlights the influence of socioeconomic realities on vaccine acceptance [39]. Younger individuals, unemployed populations, rural communities, and people with lower educational levels were more likely to express hesitancy in several settings. Economic hardship, social exclusion, and limited access to healthcare services may contribute to distrust toward public institutions and vaccination programs. In many African countries, populations facing daily economic difficulties may prioritize immediate survival needs over preventive health interventions such as vaccination.

These findings have important implications for future vaccination programs and public health communication strategies across Africa. Increasing vaccine availability alone may not be sufficient to improve uptake where mistrust and misinformation remain widespread. Stronger engagement with communities is necessary. Religious leaders, traditional leaders, community influencers, and healthcare workers should be actively involved in communication efforts because they often hold greater trust within communities than political institutions.

There is also a need for stronger digital risk communication systems capable of identifying and responding rapidly to misinformation circulating through social media. Public health messaging should be culturally sensitive, locally adapted, and delivered in clear language that communities can easily understand. One

communication strategy may not work equally across all African settings because social realities and public concerns differ considerably between countries and communities.

This review additionally highlights important research gaps. Most included studies used cross-sectional designs, making it difficult to understand how vaccine attitudes changed over time during the pandemic. Evidence evaluating interventions specifically designed to reduce vaccine hesitancy in African settings also remains limited. Future research should therefore focus on longitudinal studies, intervention-based research, and evaluation of culturally adapted communication approaches capable of improving vaccine confidence within different African populations.

Some limitations should be considered when interpreting the findings of this review. Most included studies focused specifically on COVID-19 vaccines during the pandemic period, which may limit direct generalization to other vaccination programs. Differences in study designs, target populations, and measurement approaches may also affect comparability between studies. Despite these limitations, the review provides important evidence that vaccine hesitancy in Africa is shaped by complex interactions between sociocultural beliefs, institutional trust, misinformation dynamics, perceived vaccine safety concerns, and broader health system realities.

Conclusion

COVID-19 vaccine hesitancy remains a major public health challenge across African countries despite the availability of vaccination programs and continued efforts to improve vaccine uptake. The findings from this systematic review show that vaccine hesitancy in Africa is influenced by multiple interconnected factors including sociocultural beliefs, mistrust in governments and healthcare systems, misinformation circulating through social media, concerns regarding vaccine safety, and weaknesses in public health communication. Fear of side effects, religious and traditional beliefs, low confidence in institutions, and exposure to false information emerged consistently across the reviewed studies as important barriers affecting vaccine acceptance.

The review further demonstrates that vaccine hesitancy in Africa is strongly shaped by local realities and contextual experiences. Variations in political environments, historical experiences, cultural beliefs, and healthcare system capacity influence how different populations perceive vaccination programs. These findings indicate that generalized approaches may not adequately address vaccine hesitancy across diverse African settings. Public health interventions therefore need to adopt culturally sensitive and community-centered communication strategies that involve trusted healthcare workers, community leaders, and religious leaders.

Strengthening trust in public health institutions, improving access to accurate health information, and addressing misinformation through effective risk communication remain essential for improving vaccine confidence across African populations. There is also a need for stronger investment in health literacy, digital communication monitoring, and community engagement strategies to counter false narratives surrounding vaccines.

Future research should focus on evaluating interventions aimed at improving vaccine confidence and understanding how vaccine attitudes evolve over time within different African populations. Greater attention should also be given to the role of social media, political trust, and health system strengthening in shaping public acceptance of vaccination programs across the continent.

Ethical Approval

Ethical approval was not required for this study because it was a systematic review based exclusively on published literature and publicly available reports. No human participants were directly involved, no primary data were collected, and no identifiable personal information was accessed. The review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines.

Data Availability

All data supporting the findings of this study are included within the article and its referenced sources. No new datasets were generated during this study.

Author Contributions

Egbe Derick Agbor conceived and designed the study, conducted the literature review, analyzed the data, and drafted the manuscript. Eyong Manyiyong Queenta contributed to the study design, interpretation of findings, and critical revision of the manuscript. Fietsop Ernestine Nkemta, Frida Bessem Taku Bate, and Eyong Bessemeyong Velda contributed to data interpretation, manuscript revision, and editing. All authors read and approved the final manuscript.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Acknowledgements

The authors sincerely acknowledge the contributions of researchers, public health institutions, and international organizations whose published studies and reports contributed to this systematic review. Appreciation is extended to the World Health Organization (WHO), Africa Centres for Disease Control and Prevention (Africa CDC), and other institutions involved in strengthening vaccine research and public health interventions across Africa.

The authors also appreciate the academic support and guidance received from colleagues and collaborators who contributed to the development of this review article.

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Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art030

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Private-Sector Contribution to Tuberculosis Case Notification in Nigeria: A Systematic Review and Meta-Analysis

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Cite this article as: Ariyo Abimbola, Paul Abiodun Olaiya, Ariyo Victoria. Private-sector contribution to tuberculosis case notification in Nigeria: a systematic review and meta-analysis. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art030**

Received: 19.05.2026
Accepted: 09.07.2026
Published: 30.10.2026

Article Type: Review Article

Abstract *Tuberculosis (TB) remains a leading cause of infectious disease mortality worldwide, and Nigeria contributes disproportionately to the global burden. More than half of Nigerians with TB symptoms first seek care from private providers; the private sector's contribution to national TB case notification has not been formally distilled. This review estimated the contribution following PRISMA 2020 and a registered protocol. Six databases and grey literature sources were searched from January 2000 to December 2023. Two reviewers screened records and assessed risk of bias using the Newcastle–Ottawa Scale, ROBINS-I, and JBI checklist. Proportions were pooled using the DerSimonian–Laird random-effects estimator. Heterogeneity was assessed with I^2, τ^2, and Cochran's Q and explored through subgroup and meta-regression analyses; bias was evaluated using Egger's test. Of 1,673 unique records screened, 28 studies met the eligibility criteria, and 18 studies (47,342 notifications) were included in the primary meta-analysis. The pooled private-sector contribution was 16.8% (95% CI 15.6–18.0; $I^2 = 90.7\%$; $\tau^2 = 0.028$), exceeding the WHO benchmark of 15%. Results withstood sensitivity checks. The study-level share did not change significantly over 2009–2023 (meta-regression $p = 0.678$). Contributions were higher in private hospitals (19.2%) and laboratories (21.0%) than in mixed portfolios (16.2%) or medicine-vendor channels (14.5%). No publication bias was detected (Egger $p = 0.944$). Engaged private providers account for one in six notified TB cases in Nigeria; sustaining and expanding this contribution requires an institutionalised public–private mix, predictable domestic financing, and the integration of TB notification into health insurance benefit packages.*

Keywords *Case Notification, Meta-Analysis, Nigeria, Private Sector, Public–Private Mix, Tuberculosis.*

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Introduction

Tuberculosis (TB) remains the deadliest infectious-disease killer worldwide, surpassing even HIV/AIDS in absolute mortality since 2014, and continues to claim more than one million lives every year despite the existence of inexpensive and curative chemotherapy [1]. The World Health Organization (WHO) estimates that approximately 10.6 million people fell ill with TB and 1.3 million died from the disease in 2022, with the majority of cases occurring in low- and middle-income countries [1, 2]. The Sustainable Development Goal target of ending the TB epidemic by 2030 requires an annual reduction in incidence of at least 17%, a pace currently being achieved by very few high-burden countries [3].

Nigeria occupies a particularly important position in the global TB response. The country is one of the eight nations that together account for two-thirds of incident cases globally and is consistently classified as a high-burden country for TB, TB/HIV co-infection and multidrug-resistant TB [1, 4]. Nigeria contributes an estimated 4.6% of incident TB cases globally and ranks first in Africa for absolute burden [4]. Yet, the national TB notification rate has historically lagged behind the estimated incidence, producing a persistent case-detection gap that has been described as the central operational challenge of the country's TB programme [5, 6].

A growing body of patient-pathway evidence shows that the majority of symptomatic Nigerians do not first present to public-sector directly observed treatment short-course (DOTS) facilities. Instead, the typical pathway begins in the private sector – at community pharmacies, patent and proprietary medicine vendors (PPMVs), private clinics and private laboratories – before reaching, if at all, a notification-capable facility [7, 8]. Hanson and colleagues showed that more than two-thirds of TB-symptomatic individuals in Lagos and Kano first consulted a private provider, and that fewer than one in five of these encounters resulted in a notification under the original programmatic arrangement [7]. This pattern is consistent across Nigerian zones and has been reproduced in patient-pathway studies in other high-burden settings [9].

The public–private mix (PPM) approach was developed by the WHO and partner agencies to address precisely this disjunction between care-seeking and notification [10]. Under PPM, private providers are formally engaged – through training, supportive supervision, the provision of free anti-TB drugs and diagnostics, and the introduction of standardised reporting tools – to bring their TB activity into the national notification system. International evidence suggests that effective PPM engagement can substantially increase national notification figures without diluting treatment success rates [11, 12]. In Nigeria, the National Tuberculosis and Leprosy Control Programme (NTBLCP) began to scale PPM activities from the late 2000s, supported by international partners, and a substantial primary literature has since accumulated reporting on the private-sector contribution to TB notification in different settings and time periods [13].

Despite the volume of this primary literature, no Nigeria-specific pooled estimate of the private-sector contribution to TB notification has been published, and the temporal pattern and provider-type variation have not been formally synthesised. The available individual studies report widely varying contributions – from approximately 10% to nearly 24% – depending on the engagement model, provider type, geographic location and study period [13–16]. Without a pooled synthesis, programme managers, donors and policy-makers cannot easily benchmark the Nigerian PPM programme against the WHO programmatic target of ≥15% private-sector contribution, identify under-performing settings or evaluate temporal trends. This systematic review and meta-analysis was undertaken to fill this evidence gap. Specifically, we aimed (i) to estimate the

pooled private-sector contribution to TB case notification in Nigeria, (ii) to characterise its variation by provider type, geographic zone and study period, and (iii) to assess the robustness of the estimate to risk-of-bias, leave-one-out and publication-bias diagnostics.

Materials and Methods

Study Design and Registration

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 statement [17]. A review protocol was prospectively registered with the International Prospective Register of Systematic Reviews (PROSPERO) before screening commenced. The review question was framed using the population, exposure, comparator and outcome (PECO) structure: population, TB-symptomatic individuals or notified TB cases in Nigeria; exposure, engagement with private-sector providers under PPM or equivalent arrangements; comparator, public-sector providers or pre-engagement baselines (where reported); outcome, proportion of total TB case notifications attributable to private-sector providers.

Eligibility Criteria

Studies were eligible for inclusion if they (i) were conducted in Nigeria or contained Nigeria-specific extractable data, (ii) reported a numerator and denominator allowing calculation of the proportion of TB notifications attributable to engaged private providers, (iii) used a study design of cross-sectional, cohort, programme review, intervention study or quasi-experimental design, and (iv) were published between January 2000 and December 2023. Editorials, opinion pieces, conference abstracts without sufficient extractable data, and studies in which the private-sector contribution could not be separated from public-sector activity were excluded. No language restriction was applied a priori, but in practice all included studies were in English.

Search Strategy

A comprehensive search strategy was developed in consultation with an information specialist. Six bibliographic databases were searched: PubMed/MEDLINE, Scopus, Web of Science, Embase, African Journals Online (AJOL) and the WHO Global Index Medicus. The search combined terms relating to tuberculosis ("tuberculosis", "TB", "pulmonary tuberculosis"), the private sector ("private sector", "public–private mix", "PPM", "patent medicine vendor", "pharmacy", "private hospital"), and Nigeria. Trial registers (ClinicalTrials.gov, Pan-African Clinical Trials Registry) and grey-literature sources – including NTBLCP annual reports, WHO Global TB reports, Stop TB Partnership documents and reports from major implementing partners – were also searched. Reference lists of all included studies and previous reviews were hand-searched. The final search was executed on 31 December 2023.

Study Selection and Data Extraction

All retrieved records were exported into Rayyan, where duplicates were removed. Two reviewers independently screened titles and abstracts, and then full texts, against the eligibility criteria. Disagreements were resolved through discussion and, when necessary, arbitration by a third reviewer. Inter-rater agreement was substantial to almost perfect (Cohen's $\kappa = 0.81$ at title/abstract stage and 0.88 at full-text stage). Data were extracted using a pre-piloted standardised form covering: first author, year of publication, study period, geographic location and zone, study design, provider type, denominator (total notifications or TB-symptomatic population), numerator (notifications attributable to private sector), engagement model and risk-of-bias indicators.

Risk-of-Bias Assessment

Risk of bias was assessed independently by two reviewers using design-appropriate instruments. The Newcastle–Ottawa Scale (NOS) was applied to observational cohort and cross-sectional studies, ROBINS-I to non-randomised intervention studies and the Joanna Briggs Institute (JBI) critical appraisal checklist to prevalence/proportion studies [18, 19]. Each study received a summary risk-of-bias rating of low, moderate or high. Quality-restricted sensitivity analyses excluded studies rated high risk on the relevant instrument.

Statistical Analysis

Study-level proportions were transformed to the logit scale to stabilise variance and avoid bounding artefacts at extremes. Pooling used the DerSimonian–Laird random-effects estimator [20], with back-transformation for presentation. Between-study heterogeneity was quantified using I^2, τ^2 and Cochran's Q with degrees of freedom and p-value and interpreted according to standard thresholds [21]. Pre-specified subgroup analyses were conducted by geographic zone (six WHO zones), provider type (private hospital, private laboratory, mixed PPM portfolio, PPMV/pharmacy channel), study design and study period. A random-effects meta-regression of the logit-transformed proportion on study mid-year was conducted to assess temporal trends, with results expressed as the percentage-point change per year. Publication and small-study bias were assessed visually using a funnel plot and formally using Egger's regression test of the intercept [22]. Robustness of the pooled estimate was examined through leave-one-out analyses and quality-restricted sensitivity analyses. Statistical analyses were performed in R (version 4.3.1) using the meta and metafor packages, with a two-sided α of 0.05.

Results

Search Results and Study Selection

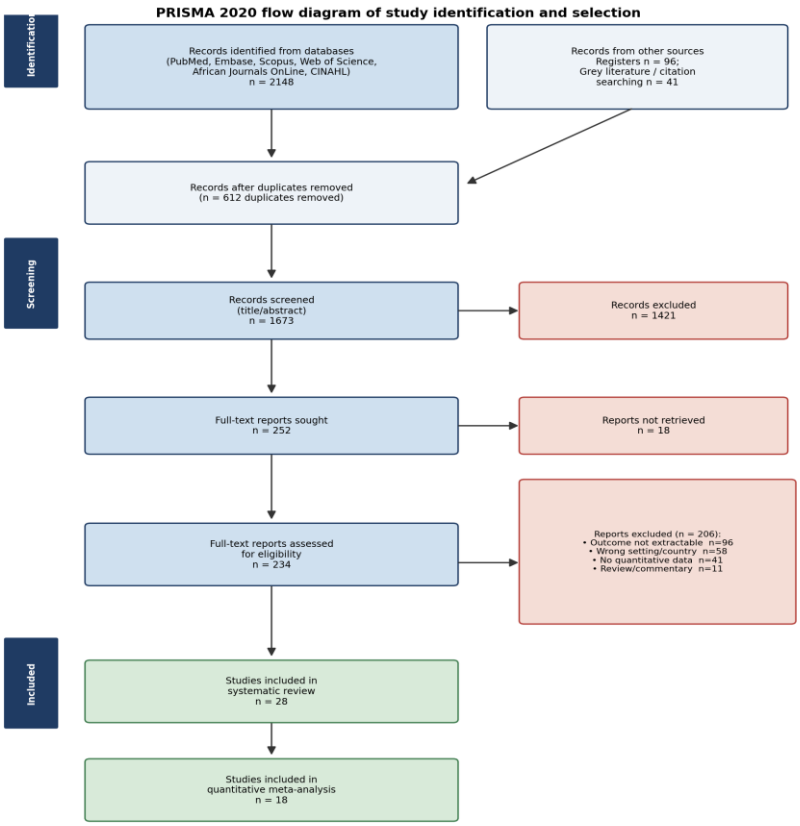


Figure 1. PRISMA 2020 Flow Diagram of Study Selection

The search identified 2,285 records across the six databases and grey-literature sources. After removal of 612 duplicates, 1,673 unique records were screened on title and abstract, of which 234 progressed to full-text assessment. A total of 28 studies met the eligibility criteria. Of these, 18 reported extractable numerator and denominator data and were included in the primary quantitative meta-analysis, comprising 47,342 notifications. The remaining 10 studies were retained for the narrative synthesis but did not provide data in a format compatible with pooling. The flow of studies through the review is summarised in the PRISMA 2020 diagram (Figure 1).

Characteristics of Included Studies

Included studies were published between 2009 and 2023 and covered all six geopolitical zones of Nigeria, with the largest concentration in the South-West (n = 7) and North-Central (n = 6) zones. Sixteen studies were cross-sectional, eight were programme reviews and four employed quasi-experimental designs comparing pre- and post-engagement periods in the same population. Engagement models included formal PPM-DOTS arrangements (n = 18), pharmacy-based engagement (n = 5), PPMV engagement (n = 3) and mixed-portfolio arrangements (n = 2). Twenty-one studies were rated low or moderate risk of bias, and seven were rated high risk; the latter were excluded from the quality-restricted sensitivity analysis.

Pooled Private-Sector Contribution

The pooled private-sector contribution to TB case notification in Nigeria was 16.8% (95% CI 15.6–18.0), based on 18 studies and 47,342 notifications. Between-study heterogeneity was high ($I^2 = 90.7\%$; $\tau^2 = 0.028$; Cochran's $Q = 183.3$, $df = 17$, $p < 0.001$), reflecting genuine variability across settings and engagement models rather than measurement error alone. The lower bound of the 95% confidence interval (15.6%) exceeded the 15% WHO programmatic benchmark, indicating that the Nigerian private-sector contribution has, on average, reached the international target. Study-level estimates ranged from 10.0% to 23.9%, with large programme reviews clustering tightly around the pooled value (Figure 2).

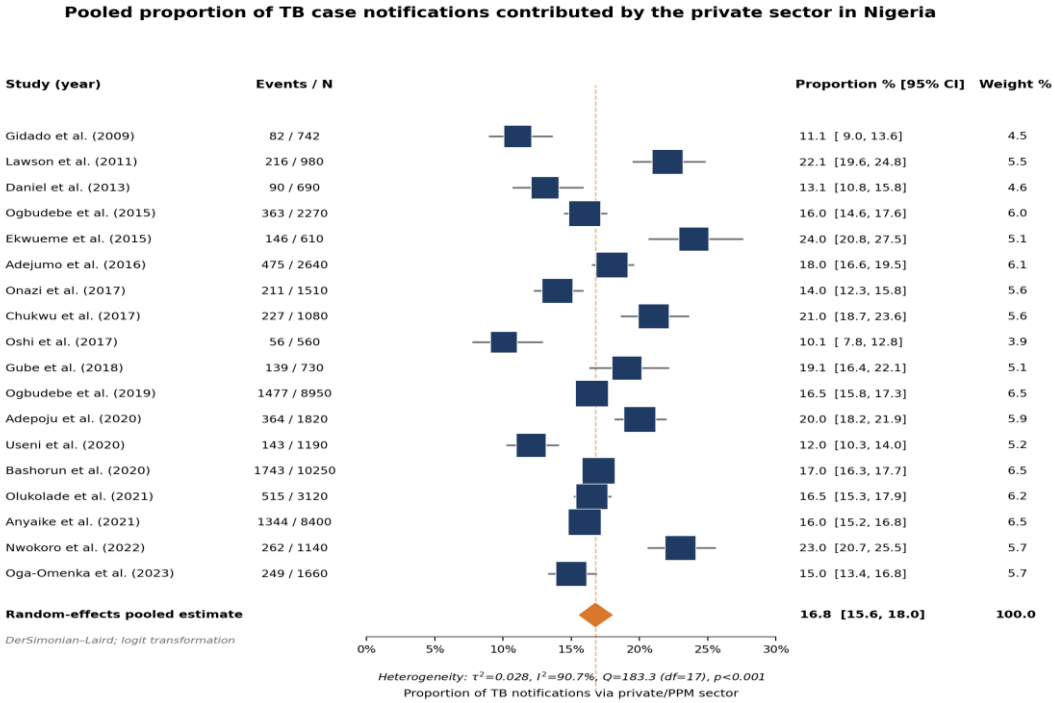


Figure 2: Forest Plot of Private-Sector Contribution (18 Studies; Random-Effects, logit Scale, Back-Transformed)

Sensitivity Analyses

The pooled estimate was robust. A quality-restricted analysis that excluded two studies rated high risk on the JBI checklist returned a pooled estimate of 16.7% (95% CI 15.5–17.9). Leave-one-out estimates ranged narrowly between 16.5% and 17.0%, with no single study materially influencing the pooled value. Restricting the analysis to studies with denominators ≥1,000 notifications yielded a pooled estimate of 16.9% (95% CI 15.7–18.1), virtually identical to the primary estimate.

Temporal Trends and Meta-Regression

A meta-regression of the logit-transformed study-level proportion on study mid-year produced a small and non-significant slope (approximately +0.11 percentage points per year; $R^2 \approx 1\%$; $p = 0.678$). This apparent stability of the study-level share should be interpreted cautiously: it occurred during a period of rapid total-notification growth at the national level and reflects parallel expansion of public-sector case-finding rather than a stagnant private contribution. In absolute terms, the number of TB cases notified through engaged private providers in Nigeria grew substantially across the study period.

Subgroup Analyses by Provider Type and Geographic Zone

Subgroup analyses revealed meaningful variation in contribution by provider type. Pooled contributions were higher in private laboratories (21.0%; 95% CI 16.4–26.6) and private hospitals (19.2%; 95% CI 14.4–25.0) than in mixed PPM portfolios (16.2%; 95% CI 15.3–17.2) or PPMV/pharmacy channels (14.5%; 95% CI 10.7–19.3). Geographic variation was also evident, with higher contributions observed in the South-East (18.3%) and South-West (17.0%) zones than in the North-East (11.1%). Subgroup contributions are summarised in Table 1.

Table 1. Pooled Estimates of Private-Sector Contribution by Provider Type and Geographic Zone

Subgroup	Studies (k)	Pooled estimate (95% CI)
Overall pooled estimate	18	16.8% (15.6–18.0)
Private hospitals	4	19.2% (14.4–25.0)
Private laboratories	3	21.0% (16.4–26.6)
Mixed PPM portfolios	10	16.2% (15.3–17.2)
PPMV/pharmacy channels	3	14.5% (10.7–19.3)
South-West zone	7	17.0% (15.4–18.7)
South-East zone	3	18.3% (15.6–21.3)
North-Central zone	6	16.4% (14.7–18.2)
North-East zone	2	11.1% (8.3–14.8)

Publication and Small-Study Bias

Visual inspection of the funnel plot showed a symmetrical distribution of studies around the pooled estimate. Egger's regression test of the intercept was non-significant (intercept = −0.12; $p = 0.944$), providing no statistical evidence of publication or small-study bias. The trim-and-fill analysis did not impute any missing studies, further supporting the absence of meaningful asymmetry in the published evidence (Figure 3).

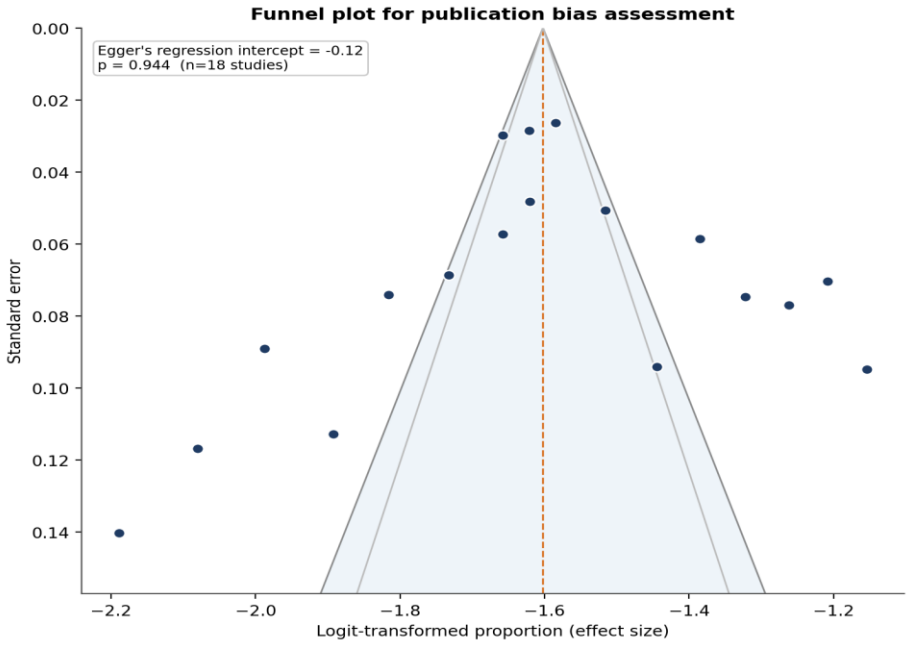


Figure 3. Funnel Plot with Egger's Test Annotation

Discussion

This systematic review and meta-analysis provides the first Nigeria-specific pooled estimate of the private-sector contribution to TB case notification. Engaged private providers contribute a pooled 16.8% of TB notifications in Nigeria, a substantial, precise and robust contribution that exceeds the WHO programmatic benchmark of 15% [10]. The lower bound of the confidence interval lies above this benchmark, indicating that on average, the Nigerian PPM programme has achieved international targets. This finding represents a meaningful programmatic success and should reinforce confidence in continued investment in private-sector engagement.

The apparent temporal stability of the contribution at the study level should not be misread as stagnation. Because both the numerator (private-sector notifications) and the denominator (total notifications) grew substantially over the period, a stable ratio is fully consistent with a substantially rising absolute private contribution. This denominator effect is an important interpretive caution that applies to all proportion-based coverage indicators and explains why pooled coverage ratios can plateau even as programmatic activity expands [23]. Policy-makers and donors should consider both relative and absolute metrics when assessing PPM performance trajectories.

The provider-type and zonal gradients identified in this synthesis are programmatically actionable. Private hospitals and laboratories contribute disproportionately on a per-facility basis, suggesting that further investment in formalising arrangements with diagnostic providers – in particular GeneXpert-equipped private laboratories – is likely to yield additional notifications [24]. By contrast, PPMV/pharmacy channels, which represent the most numerous and accessible category of private providers nationally, contribute a lower share, indicating untapped potential and suggesting that engagement models for this channel warrant intensified attention [25]. Geographic disparities, with lower contributions in the North-East zone, may reflect both security-related access challenges and weaker private-sector density and engagement infrastructure in conflict-affected areas [26].

The findings of this review are consistent with international PPM evidence. Multi-

country reviews have reported private-sector contributions of 10–25% in high-burden settings with active engagement, and similar contribution patterns have been documented in India, Indonesia, the Philippines and Pakistan [11, 27, 28]. The Nigerian pooled estimate sits centrally within this international distribution and suggests that, while there remains substantial scope for expansion, the Nigerian PPM programme is broadly comparable to peer programmes in other high-burden settings.

The strengths of this review include adherence to the PRISMA 2020 statement, a prospectively registered protocol, comprehensive search across six databases and grey-literature sources, dual independent screening and risk-of-bias appraisal, use of an appropriate variance-stabilising transformation for proportion meta-analysis, and triangulated robustness checks (leave-one-out, quality-restricted and trim-and-fill analyses). The absence of detectable publication bias supports the credibility of the pooled estimate.

Several limitations should be acknowledged. First, the evidence base is predominantly observational, and a small number of quasi-experimental studies cannot fully control for secular trends in TB case-finding. Second, residual heterogeneity remained high after subgroup analysis, indicating that important moderators of the private-sector contribution – plausibly including engagement intensity, programme maturity and ambient health-system capacity – are not fully captured by the variables extracted. Third, the review was restricted to English-language publications and, although unlikely to omit substantial Nigerian-context evidence, this may have excluded some grey literature. Finally, the pooled estimate is best interpreted as a central tendency across heterogeneous settings rather than a single national constant; site-specific PPM performance should always be benchmarked against locally relevant comparators.

Conclusion

Engaged private providers in Nigeria contribute approximately one in six notified TB cases, a substantial and statistically robust contribution that exceeds the WHO programmatic benchmark of 15%. The private-sector contribution varies meaningfully by provider type and geographic zone, with higher yields from private hospitals and laboratories than from medicine-vendor channels, and lower contributions in the North-East zone than elsewhere. These findings support institutionalising public–private mix as a permanent, domestically financed component of the national TB response, advancing mandatory notification with confidentiality safeguards, and integrating notified TB cases into health-insurance benefit packages to address the financial-disincentive barriers reported in the qualitative literature. Targeted strategies to deepen engagement in the under-performing PPMV/pharmacy channel and in security-affected northern zones are essential to close the remaining case-detection gap and accelerate Nigeria's progress toward the End TB Strategy targets.

Conflict of Interest

The authors declare that there is no conflict of interest.

Acknowledgements

The authors wish to acknowledge the staff of the National Tuberculosis and Leprosy Control Programme (NTBLCP), Federal Ministry of Health, Nigeria, for facilitating access to programmatic reports. We also thank the information specialist who assisted with the search strategy and the colleagues who provided constructive feedback on earlier drafts of the manuscript.

Ethical Approval

Ethical approval was not required for this study as it is a systematic review and meta-analysis based on previously published data and

publicly available programme reports. No primary data were collected from human participants. All included studies in this review had received ethical approval from their respective institutional review boards as reported in their original publications.

Authors' Contributions

Ariyo Abimbola conceived and designed the study, developed the search strategy, led screening and data extraction, conducted the meta-analysis and drafted the manuscript. PAO contributed to the protocol development, served as the second independent reviewer for screening and risk-of-bias appraisal, contributed to data interpretation and reviewed the manuscript. All authors read and approved the final manuscript.

Data Availability

The datasets generated and analysed during the current study, including the full extraction table and analysis code, are available from the corresponding author upon reasonable request.

Funding

This study did not receive any specific funding from public, commercial, or not-for-profit funding agencies.

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Journal: Texila International Journal of Academic Research
https://doi.org/10.21522/TIJAR.2014.13.04.Art031

ISSN: 2520-3088
Volume 13 Issue 4, 2026

Navigating Implementation: A Qualitative Exploration of the Integrated Disease Surveillance Response in Zambia

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Cite this article as: Precious Kalubula Chisale, Nkomba Kayeyi. Navigating implementation: a qualitative exploration of the Integrated Disease Surveillance Response in Zambia. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art031**

Article Type: Case Report

Received: 27.08.2026

Accepted: 22.09.2026

Published: 30.10.2026

Abstract *Surveillance is an imperative for health systems to thrive and respond to emerging and re-emerging diseases. It is even more important for planning and technical planning for public health emergencies. Having a system that integrates various components not only improves a country capability to prepare for such events but also, it provides a platform for continuous reporting and steady flow of information. A qualitative study conducted 14 key informant interviews with officers who play a pivotal role in the implementation of the Integrated Disease Surveillance System (IDSR) from eight districts of five provinces executed. Various common themes emerged, these were roles and oversight in implementation, enablers of IDSR, implementation challenges/barriers, intersectional coordination and recommendations for improvement and sustained use. A consensus emerged regarding the improvements in reporting, which after the IDSR is considered timelier, prompt, accurate and efficient. This implies that as a country, there has been an improvement in case detection and management. However, gaps still remain in capacity emanating from attrition of designated surveillance staff which threatens sustainability of implementation.*

Keywords *Health Systems Management, Integrated Disease Surveillance Response, One Health, Public Health Emergencies, Re-Emerging Diseases.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art031

Introduction

Disease surveillance is an important foundation upon which strong public health systems are built to effectively and efficiently respond to disease outbreaks [6, 10]. A strong public health system is one that can identify an outbreak early and respond quickly to save lives. This is why the integrated Disease Surveillance and response system is important. Ibrahim et al defines it as a health system specifically designed to systematically and continuously collect, analyse and interpret public health data which is used for public health action in the case of an outbreak [8].

In the past, most of the African countries implemented disease surveillance in uncoordinated manner such that each disease had its own surveillance structure and reporting formats. This brought in challenges such as splitting of limited resources and delays when it comes to identifying disease outbreaks [10].

To bring together existing fragmented surveillance systems in different countries, the World Health Organisation (WHO) under the regional office for Afrcia (AFRO) introduced the Integrated Disease Surveillance Response (IDSR) in 1988, initially as the Integrated Disease Surveillance [26]. The strategy was adopted for developing and implementing broad public health surveillance and response systems in African countries. Later, the strategy was changed to Integrated Disease Surveillance and Response (IDSR) to emphasize the linkage between response and surveillance [26] as shown in Figure 1.



Figure 1. WHO IDSR Flow Chart and its Core Functions

Some authors argue that the IDSR system was designed to provide a common approach for member states to strengthen the detection, reporting, investigation and control of priority diseases through a comprehensive framework [9, 12].

Figure 2 below shows the surveillance chain or structure that Zambia has adopted which is similar to that in Liberia [17]. It begins at the community level comprising of community-based volunteers who live and work within communities and can pick out any emerging

public health events. The community-based volunteers then report to the nearest health facility of any public health event. The health facilities, through facility surveillance focal point person, verifies the information and compile surveillance reports from communities and report to the district Surveillance officer who also verifies health facility reports and report to the province. After receiving the reports, the province also reports to the Ministry of Health[10] through the Zambia National Public Health Institute (ZNPHI). However, with the adoption of an electronic IDSR (eIDSR) system in Zambia, surveillance data is entered at the facility and district level while the province and National verify the correctness of the data and confirm cases. Feedback on submitted surveillance reports from the National flow through the same channel up to the community.

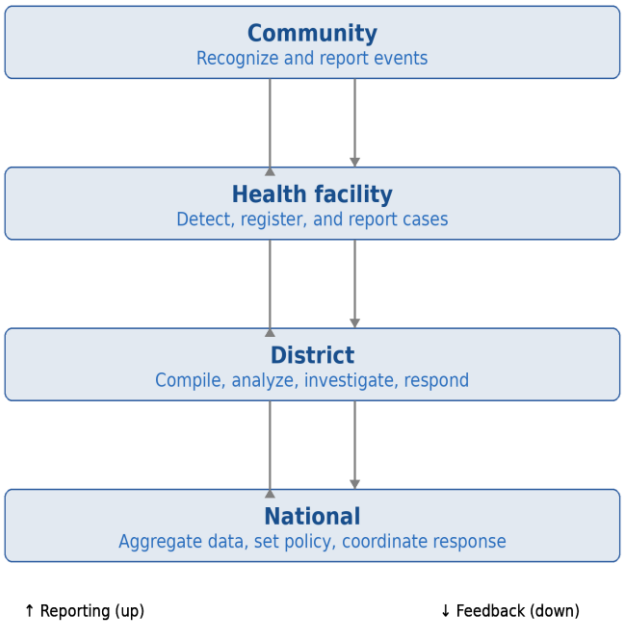


Figure 2. WHO IDSR Multi-Level Breakdown

The adoption of an electronic IDSR system in Zambia was in response to the many challenges that come with the paper-based IDSR system previously used for reporting, tracking purposes and immediate response. In this system, officers had to write paper-based reports and submit them to the next office. This comes with challenges of duplication, reporting errors, legibility and lack of timeliness in the reporting process [1, 20].

Even with the adoption of an electronic IDSR system in Zambia accompanied by an established surveillance structure as shown in figure 2, the implementation and management of the e-IDSR system have not been seamless. At the centre of the Zambia's Surveillance chain are designated Surveillance Officers at District, Provincial and National level. While they play an important role in the implementation and management of the IDSR system in Zambia, the researcher was unable to find studies that have been conducted to capture the experiences of Surveillance officer with the IDSR system covering all the 10 provinces of Zambia. The studies that have been conducted in Zambia have focused on selected Districts or provinces and certain aspect of the IDSR system. Therefore, this study bridges this gap by capturing the experiences of Surveillance officers in all the 10 provinces representing a diverse list of districts of Zambia.

Materials and Methods

Study Setting

The study covered the 10 provinces and 10 Districts of Zambia in order to have a

comprehensive understanding of the IDSR system in Zambia from the perspective of the Surveillance Officers at National, Provincial and District level. The study covered Northen, Eastern, Central, Western, Luapula, North-Western, Northern and Copperbelt provinces of Zambia. The districts that were covered included Chembe, Mansa, Nchelenge, Kaoma, Kasama and Mkushi. Some district officers interacted with, were from boarder areas which are prone to emerging diseases and outbreaks due to migration issues.

Study Design

The study used a qualitative exploratory design [11,24]in its endeavour to explore the implementation of the integrated disease surveillance and response in Zambia from the perspectives of surveillance officers from the National, Provincial and district level. Key informant interviews were conducted with selected Surveillance Officers at three level of the ISDR implementation structure, except for the facility and community level.

Sampling Procedure

The researcher purposefully sampled [2, 18] all the officers designated as Surveillance officers in the IDSR implementation structure, except for health facilities. At National level, the researcher sought to interview surveillance officers at the Zambia National Public Health Institute. All ten provincial and district surveillance officers were selected. This means that within each province, two districts were sampled based on a rural or urban status of the district for the study to establish a comprehensive understanding of the ISDR system in Zambia. The working sample included 10 health facilities to make 33. However, the working sample was narrowed to 22, leaving out the healthcare workers because the officers covered all details including what happened on the ground after reaching data saturation [5, 16] during the data collection process. Table 1 below shows a summarised working sample. However, only 14 were interviewed as the study was guided by the principle of data saturation. Summary of the study sample and actual interviews conducted is provided in Table 1.

Table 1. Distribution of Sampled Surveillance Officers by Administrative Level and Number of Interviews Conducted for the Qualitative Study

Level	**No. of Sampled So Officers**
National	2
Provincial	10
District	10
Health facility	0
Total	22
Interviews Conducted	
Actual Interviews	14

Data Collection

Data collection was conducted between April and July 2026. Qualitative data was collected from sampled key informants using an interview guide. The interview guide had four sections covering the ISDR implementation in Zambia in term of 1) knowledge and awareness of the ISDR system, 2) experiences with the IDSR system and 3) recommendations for improvements. Specifically, key informants were asked about their experiences with the IDSR, the transition from paper-based surveillance and reporting to the e-IDSR, the Successes of the integrated IDSR system, its demerits and what could be changed to make

the current system work better as well as how they interact with other partners in the disease surveillance response.

Aside from having physical interviews especially for key informants in Lusaka Province, some interviews were conducted via mobile phone at the request of the key informants as they were busy during the day while others it was due to long distances to where key informants are located. Two research assistants were engaged and trained to assist with data collection. However, the interview guide was developed and tested by the Author. The duration of the interviews ranged between 25 minutes to 60 minutes. At the end of each interview, audio interviews were transcribed by the research assistants within two days after the interview and checked for accuracy by the Author.

Data Analysis

The study utilized thematic data analysis to facilitate the analysis process of qualitative data. Both deductive and inductive methods of analysis was used during the analysis process. While major themes naturally emerged from the interview transcripts, the study objectives and questions were also used as a guide during the analysis process. The themes were generated based on the four objectives of the study. The transcripts were read severely by the Author to have a deeper understanding of the data on the transcripts. The coding and analysis of the data was done by the Author.

A rapid qualitative analysis of the data, using a rapid qualitative analysis matrix [7] was conducted by the team. As in any qualitative inquiry, the data reduction[7, 27] process was started from the first interaction. The notes were put together during the interactions to extract meaning and ensure that the data collected in the process improved the quality of the subsequent interviews. Furthermore, this was to allow for analysis that refines, organizes, concentrates and rides of data as well as explains data in a manner such that the final analysis can occur coherently [3].

The matrix was structured using the questions below. These formed the domains through which the findings were summarized and took note of the quotes that arose. The domains were summarized as role in implementation, Enablers of IDSR, Challenges/Barriers, Intersectional coordination, recommendations and other notable findings.

Questions

1. What enablers exist in the IDSR in Zambia?
2. What role do surveillance officers play in integrated disease surveillance response in Zambia?
3. What challenges do surveillance officers experience in implementing IDSR at National, Provincial and District levels?
4. How is inter-ministerial/sectorial coordination actioned/enacted during outbreak response?
5. How would the IDS response be improved from the lessons learned?

Study Credibility and Trustworthiness

This was achieved by recording the actual interviews on a digital recorder and then transcription was done within a 24-hour window period to ensure that the transcripts speak to the audio interviews. To manage personal bias, reflexivity was used during data collection by engaging two research assistants who also assisted with transcription of the interviews. The study also ensured that the findings reflected the views of the participants by using participate quotes. Lastly, data triangulation was achieved by comparing the views of surveillance officers at both district, provincial level and national levels. This was to ensure trustworthiness according to Lincoln and Guba [28].

Results

After reading and sorting of the data and familiarisation by the researcher, various common themes emerged. These were roles and oversight in implementation, enablers and benefits of the IDSR, implementation challenges, intersectional coordination and recommendations for improvement and sustained use. The researcher and the team had connectivity and continuous training as sub-themes under the recommendations. The results are present under each section below.

Roles and Oversight in Implementation

Participants frequently noted that the role of surveillance officers is to coordinate surveillance activities in their jurisdictions be it at National, Provincial and District levels. One participant at district level explained that "……. *I coordinate the activities of disease surveillance and response system. So, whenever a facility records an event….. I am able to analyse that trend and then inform the relevant teams, then we respond* …." (DKII 1). The study participants consistently described themselves as an important link for the flow of surveillance information as they ensure that accurate surveillance data moves from the community to the health facilities and from the health facility to the district through to the province and eventually to the National.

They further shared that they had to ensure that all activities, cases, conditions and events were tracked on time and reported as required. They frequently noted that it was part of their role to ensure that reporting and investigations were undertaken at both facility and community level. Furthermore, they highlighted the importance of working with other partners in executing their mandate as it provides them with a flow of information thus keeping abreast. They are also responsible for update on disease and conduct active case search ensuring the level of priority. Officers are also tasked with providing guidance to necessary personnel on sample collection as well as investigation of cases, follow-ups, contact tracing for all positive case of both outbreaks and notifiable diseases. Furthermore, they ensure close monitoring of activities implemented under event-based surveillance (EBS), where signals and events are uploaded in the system. Additionally, they monitor the key performance indicators of the vaccine preventable diseases, timeliness and completeness.

> *"I collect and compile and analyse surveillance data from the facilities...ya, and also, I do eehh... aaa... epidemiological bulletins, situational reports.... we also compile and also prepare and update monthly disease and vaccine trends. Conduct weekly active case search from the facilities, following the levels of priority. Ya, enlist all suspected cases and all aaa.... suspected cases are reported timely to the next level which is the province …We establish and aaaa… maintain a database of all trends… surveillance for the patients in the facilities. We also ensure that the IDSR standard case definitions are available in the facilities. We monitor the key performance indicators of the vaccine preventable diseases, timeliness and completeness...". (DKII02)*

Furthermore, overall monitoring is provided by the Zambia National Public Health Institute who provide support to relevant officers from various partners including WHO. They provide necessary resources by mobilizing what is required on the ground to ensure the smooth flow and efficient implementation of IDSR. Among these services provided include distribution of transportation support, electronic gadgets for timely data capture, analysis and reporting of surveillance activities. A surveillance officer at National level explained that:

> *"Working with the Zambia National Public Health Institute, which is ZNPHI… So, they made our work easier. For example, in 2023, they procured laptops countrywide for all the district*

surveillance officers. So early this year, they again procured tablets… that should be countrywide in short …all the facilities have tablets, except the four that were recently opened. So, they have tablets at facility level where they are entering this data…". (DKII02)

"Partners have really been helpful, ZNPHI, CDC have" (KII04)

The findings of the study revealed that Provincial Surveillance officers play an advisory role to the Ministry of Health and other stakeholders within their provinces. They shared that they provide technical guidance and guide decision making in the case of an outbreak. One Provincial Surveillance officer explained that "…. *My role is to provide disease surveillance data that influence decision making, planning and intelligence in order to protect the population in the province and the country at large…...*" (PKII 3). The surveillance data is used during planning meetings as a basis for making decisions at provincial and national level.

Enablers and Benefits of IDSR

Prior, reporting was challenging given the limitations of paper-based systems including it being time-limiting and consuming, travelling long distances to submit reports as well as legibility of different handwriting styles of the reporting officers. IDSR saw the transition from paper-based reporting to electronic reporting. This has made provision for real time reporting and hastened processes were reviews and analyses can be done promptly. This has also improved the response to early warning signs and initial response.

"For that paper to reach…, it will take a little bit of some time. So, with the coming of the new second edition, where we have integrated the IDSR, where we are using electronic platforms, I think we have real-time information, because what is done now is we have trained people, even in the community, from event-based surveillance, where data is entered as quickly as possible into the system, and then we can review that all at once, …. where it needs to go. So, basically, we have seen a big improvement in terms of reporting, and then improvement in early warning and initial response" (KII003)

Furthermore, most participants reported having received motorbikes to aid with transportation of samples and personnel who needed to go in for verifications or to follow-up on alerts. One participant when asked to make recommendations that would assist the district, they said:

"That's been sorted out. Mm-hmm. So now I'm here thinking, okay, what else do we need? Mm-hmm. We used to cry for reporting tools. Mm-hmm. The booklets. Mm-hmm. The ND tools. We say, no, we are tired of making copies. But that has been sorted out. Mm-hmm. Booklets have been distributed" (KII05)

Additionally, one participant echoed that updates made to IDSR and decentralization had made surveillance and reporting easier and more efficient since before facilities spent more time on data entry than analysis.

"If there is a notifiable medical condition, they are able to enter that at facility level since they now have a user account. So, I think the updates or additions that have been added to the IBSR has really been a game changer. I think it's making work easy… even for colleagues at district level, because now they will have a lot of time to actually look at their data and run a bit of analysis, like where we're coming from, where they [were] spending more time on data entry" (KII07)

Improved Event-Based Surveillance

The study noted that through the trainings provided at different tiers of health workers including the community-based volunteers (CBVs) there has been improved disease and case reporting and tracking systems.

> *"I think that has been working well for us. Mm-hmm. Yes, because I can give you an example of the MPOPS cases which were detected last year…. I think those were picked under event-based surveillance. That was before they reached the health facility" (KII06)*

Intersectional Coordination

Intersectoral coordination was one theme that stood out as an important theme for ISDR in that Ministry of Health has harnessed support from other line ministries to tackle disease surveillance and emergency preparedness. They noted that the one health approach has proved advantageous and beneficial for the response and health systems. Moreso, they echoed that one health approach has improved surveillance of human animal interactions and threats posed by sharing of boarders with countries that have incidents of important animal bites such as Jackals and foxes. These are important for prevention of diseases such as rabies but as well as prevention of emerging and re-emerging diseases that may be caught from interacting with such animals.

> *"The response from stakeholders has been excellent, aaaa for example, in our district. I remember when we had the Mpox outbreak, ... over 20 confirmed cases of Mpox that we had. So, we had stakeholders coming on board, contributing, buying food, charcoal, just to strengthen aaaa isolation, aaa that was really a good thing. But by and large, what I can say, issss the response, we are okay, and now, we are battling with human-animal conflict...As we speak now.... we have got these, we are bordering, so, we have animal bites, like jaguar bites, fox bite on the border side with Congo, and aaaa rabies is nowhere to be seen. But we have the stakeholders using the One Health approach, ... where they procure this anti rabies, ...and we respond timely to the victims that have been bitten by wild animals. So, in a nutshell, we are collaborating very well as a district, and I'm happy about that" (DKII06)*

Additionally, they noted that communication has improved given the forming of one health committees and epidermic preparedness committees. This has seen the reporting of cases that were once a challenge to report or track. They cited examples such as dog bites and other zoonotic diseases that pose a threat to human health.

> *"...depending on what we are dealing with at that particular time, other aligned ministries are able to come in. Mm-hmm...for example, with VET...If we've got an increase in dog bites. we ...engage VET as well as the local authority that is the council. Mm-hmm...So we could sit and look at what is happening, what can we do about it. Mm-hmm. So, there are aaa times when we sit down and just try to compare the cases…" (KII05)*

Implementation Challenges/Barriers

Staff Attrition and Capacity Building

All participants alluded to staff attrition due to transfer of surveillance designated officers from one district to the other but also from one department to another being an important challenge they face in the various offices. Moreso, they argued that those trained in IDSR move without continuity of service because those who remain may have not been trained. This leaves a gap for smooth running of IDSR services. This was tied to capacity building as a gap that is important to note.

Other challenges shared were delayed roll-out and systemic challenges as a result of lack of resources to use for other stations to also

benefit from IDSR. Moreso, these facilities have a limitation of electronic gadgets for reporting in spite of having some form of improvement in this view.

> *"So, the main challenge is the delayed roll-out, and those systemic challenges arising from maybe lack of resources. Because our target, according to the population standards, is to at least train 80% of the staff who work in the health sector…in IDSR, so that we can get a response to some of the challenges that we have. So, mostly, what has been the problem is, mostly speaking, is the resource to roll out the IDSR to the lower levels. And then the other thing, maybe electronic gadgets, though we have seen some improvements in terms of electronic gadgets for reporting. So, mostly that has been the challenges, because we haven't reached out to a lot of people in terms of getting capacity to get a response to a challenge" (KII03)*
>
> *"And the other one is also issues around inadequate trained community-based volunteers in the event-based surveillance" (KII07)*

Recommendations for Improvement and Sustained Use

Respondents echoed a number of recommendations for best practice but also to improve the current challenges faced. Under this one theme emerged strongly which is resources for sustained use. They shared that connectivity and transport support as well as capacity building through continuous training was not only imperative but required. Community engagements were also proposed through ensuring that more CBVs were trained.

> *"……community-based surveillance is very important because it bridges the gap between the community and health facilities…. we have community health volunteers who have been trained to identify specific conditions or symptoms such as clustering of cases, unusual deaths or conditions with endemic potential" (DKII 2)*
>
> *"……..inadequate trained community-based volunteers in the event-based surveillance. Most of these public health events are happening in the community, and we need to have* those disease detectives at community level……" (PKII 1)

Other participants suggested training for public health officers should be prioritized as also by saying *"……there was so much focus on our colleagues under public health... those under case management need to be trained in the IDSR because once they are trained, it will be very easy for them to detect these cases... they are the first contact to these suspected cases……."* (PKII 1)

Resources for Sustained Use

Connectivity and Transport Support

Some participants recommended that ensuring that facilities and surveillance officers had reliable internet access is imperative for sustainable use of the IDSR. They said that the system in itself is very reliable and it enhances disease surveillance processes. They provided examples of how the challenge of connectivity as a barrier can be rectified, saying that connections like star link work even in remote areas where the local network is a challenge.

> *"Starlink can help so that everyone can have access because connection affects timely reporting." KII01*

They further suggested that transport was required especially for those facilities that were based in far flung areas to facilitate reporting as well as verification of events and alerts reported under EBS.

Continuous Training

Participants across the interactions proposed continuous training as a recommendation for community-based surveillance as well as a tool to ensure continuity of surveillance processes

cut down due to attrition. Additionally, they argued that this training should be provided to all those that have access to the IDSR systems on how to improve the dashboard as well as for data analysis. They argued that this would enhance evaluation of trends in disease patterns as well as quality of reporting.

> *So, I've got 86 facilities. Then out of those 86 facilities, we've only managed to train 56 facilities in IDSR. So, if that agenda can be pushed to train the remaining facilities, that could be better. It would enhance the surveillance in the district KII05*

One participant suggested that IDSR training should be embedded in curriculum so that those health care workers replacing those leaving already know what they are to do, thus bridging the gap between attrition and non-performance.

> *…. for now, I'm seeing much of the problem that we're having is lack of capacities in some of the facilities. ...So, we are suggesting…. maybe we can streamline the trainings, the training institutions, aaaa…let them [it] be part of their curriculum, so that as they are about to graduate, we add to the curriculum overall, and the trainees that are about to graduate will be part of the system [IDSR]. We should ensure that the people that are already in the facilities, at least, we train about 80% (KII04).*

While this was suggested, one of the officers from the national level shared that this was being done as an initiative called pre-service training to ensure that all healthcare workers are exposed to IDSR early on to cushion challenges that come with staff attrition.

> *Yeah, pre-service [training] entails that we are going to the universities, and we are asking these universities that we need to come up with a curriculum together…. So that even as you[universities] are training your nurses, your clinical officers, your doctors, they need to know that there is this program called IDSR (KII14).*

Discussion

This study is the first to explore the implementation of IDSR in Zambia that has broadened the scope of review to the whole country by interviewing officers from the province and the districts. Despite this study being qualitative and limiting the generalisability, the study provides an in-depth analysis of the experiences on the ground as well as the challenges and the recommendations from the perspective of the users of the system. Moreso, it presents ground for solutions that are not only practical but sustainable. From literature, most studies in Zambia examined IDSR in line with a specific disease especially Cholera and some only explored an aspect of disease surveillance mostly considering the challenges [14, 15]. This study explored the experiences in totality, including challenges as barriers, enablers and what can be done to improve the response and ensuring sustainability going forward.

Moreso, this study provides insights covering a longer time period exploring views of how it has evolved through time, it broadens the scope of inquiry thus bring out results that cover re-emerging diseases like that of Polio in Zambia and how IDSR plays an imperative role for detection and response [17, 20].

Another important finding is that in regard to the One health approach taking centre of the response especially for districts that share boarders with other countries. This puts emphasis on important events such as jackal bites, fox bites and mpox. Similar with other studies, it cements the importance of using the one health approach which provides a broad and effective framework for addressing future pandemics [22, 23]. Additionally, the study discusses the importance of intersectoral response bringing to light issues and events such as dog bites, measles, polio and road traffic accidents including motorbike accidents.

Similarly, a study done in India [25] established that this approach is vital because resources are combined to collect information including on traffic accidents from a single focal point at each level than using scarce resources to maintain vertical activities. They further argue that the Integrated Disease Surveillance Project (IDSP) integrates both public and private sector by involving the private participation which is the same with IDSR being implemented in Zambia currently.

The study in India further suggests that gaps in receiving health information from the urban areas needs to be bridged urgently [25] but our study found that the gap that needs to be bridged is that of receiving and reporting in rural areas' given limitations in connectivity in these areas.

Similar to our findings, fall et al [4, 17]found that some of the 44 countries implementing IDSR in Africa had initiated IDSR training at subnational levels, commenced community-based surveillance, event-based surveillance, electronic IDSR and had a weekly/monthly bulletin for sharing IDSR data. This is imperative as it has improved overall public health systems and initiatives. However, gaps remain especially with inconsistent funding or inadequate funding to ensure sustainability of implementation including for training and resources. Similarly, Onmwe [19] argues that participants recommended for improved funding and increased resource allocation. This finding was consistent with the recommendations brought forward by this study participants. Funding is a core support function of IDSR and as such, should be prioritised for continued and functioning response for Zambia but the region too.

Data is available and it is possible to detect diseases and prevent public health events harnessing the existing structures and resources available. The researcher presents this in Table 1 and discuss the five main domains of CFIR [3, 21] and how these fits in the current representative of IDSR in Zambia from the findings, which can be extended to other settings with similar characteristics. Under the domain Innovation, IDSR is the main innovation which has seen the establishment of committees like epidemic preparedness and one health committees, frequent collaborative discussions through multisectoral approach and training for improved outcomes. Some authors argue that this leads to effective coordination and collaboration vital for tackling zoonotic diseases [22]. More importantly, the innovation domain includes the transition from a paper-based IDSR system to an electronic ISDR system which has come with the provision of electronic devices such as phones and laptops for timely reporting.

The outer setting importantly supports the intersectoral collaboration, partners reporting timelines, periodic update of the IDSR implementation guidelines that includes latest revision to incorporate emerging public health threats. An important feature of the IDSR implementation is community-based volunteers who live and work within communities and play an active role when it comes to identifying public health events and reporting to health facilities. For these to be active and efficient, the researcher argues that targeted training and capacity building is necessary. Agreeing with other authors, external funding is also important to complement the limited resources from the Government [13]. However, the sustainability of the IDSR system ultimately depends on government ownership and commitment to adequate financing, as reliance on donor funding is not a viable long-term strategy and may be withdrawn at any time.

In terms of the inner setting domain, it was established that internet connectivity and transport support are important features that support the functionality of the IDSR system especially in view of the adoption of the e-IDSR system. However, for rural districts, it is challenging to actualise this because internet connectivity is a big challenge. Another important feature is partner support and multisectoral coordination among lines

ministries that include Health, Fisheries and livestock as well as Agriculture among others. The IDSR implementing and reporting structures provides a well-coordinated system for timely identification of public health events and feedback mechanism. Finally, laboratory equipment and medical supplies support public health interventions in response to the IDSR feedback mechanism. However, these required to be well stocked for effective management and implementations of the public health interventions.

The individual domain consists of the personal attributes of the people handling the surveillance functions such as skills and competencies adequate training and capacity building. This is the core of the response because it makes up the drivers of implementation. This study highlights the need to build capacity as an important need and opportunity for improving surveillance. However, the study is limited by only including the officers attached to the ministry of health and did not explore the perspectives from those in other line ministries. The study findings were aligned with the five CFIR domains to illustrate key implementation factors influencing IDSR in Zambia, as shown in Table 2.

Table 2. Mapping of Integrated Disease Surveillance and Response (IDSR) Implementation Findings in Zambia to the Consolidated Framework for Implementation Research (CFIR) Domains

CFIR Domain	Definition	Results Themes
Innovation	The intervention, program, or practice being implemented - its evidence strength, design, complexity, cost, and adaptability.	IDSR as main innovation Establishment of committees like epidemic preparedness committee one health strategy Frequent collaborative discussions Training and capacity building Electronic ISDR Provision of electronic gadgets (Phones and laptops)
Outer setting	The broader context surrounding the organization -policy, external pressures, partnerships, patient/community needs.	Periodic updates of IDSR guidelines technical support Policy guidance Reporting timelines Quality assurance processes Intersectoral collaborations Donor funding Community based volunteers
Inner setting	The implementing organization itself - culture, leadership, structure, available resources, communication.	Connectivity and transport support Partner support considered an important resource Continued reporting structures with IDSR IDSR implementing structure Medical supplies Laboratory equipment Health workers, Government funding Supportive supervision

Individuals	Roles and characteristics of the people involved - capability, motivation, opportunity, need, and innovation deliverers/recipients.	Data management Quality assurance Supervision Reporting and feedback Community expansion through CBV Trainings Capacity building
Implementation process	The activities and strategies used to implement the innovation - planning, engaging, doing, reflecting and evaluating.	Continuous training Meetings with other stakeholders Intersectoral collaborations Staff attrition and capacity building as an evaluation of the process and improvement suggestion Improved event-based surveillance Provision of electronic Gadgets like phones and laptops Internet connectivity e.g. Starlink

Conclusion

IDSR has improved the reporting, timeliness, completeness and promptness of the response to cases and events in the health system. It has been pivotal in detection and management of emerging and re-emerging diseases but also highlighting important events such as accidents including motor bike accidents. However, it is imperative to be put in place measures that will assure sustainability of IDSR such as stable consistent funding, continuous training of relevant personnel, building capacity at facility levels, as well as harnessing the one health approach. The one health approach provides potential for collaborative action among animal, environmental, human and health sectors to addressing and preventing anticipated pandemics. Moreso, integrating the community-based volunteers and equipping them with necessary skills is not only vital but timely.

Conflict of Interest

The author serves as a Surveillance Officer within the public health sector and is engaged in activities related to disease surveillance and response in Zambia. This professional role may be perceived as a potential source of bias regarding the evaluation of the IDSR system. To mitigate this risk, the study followed established scientific methods, and findings were reported objectively. The author declares no financial conflicts of interest.

Ethical Approval

Ethical approval for this study was obtained from the National Health Research Authority (NHRA), Zambia (NHRA-R-4104/23/04/2026) and the University of Zambia Biomedical Research Ethics Committee (UNZABREC) (Reference No. 7902-2026) prior to study implementation. Administrative permission to conduct the study was obtained from the relevant health authorities. Participation was voluntary, and informed consent was obtained from all participants before data collection. Confidentiality, anonymity, and privacy of participants were maintained throughout the study, and all data were securely stored and used solely for research purposes**.**

Data Availability

The datasets generated and/or analysed during the current study are not publicly

available because they contain information that could compromise the privacy and confidentiality of study participants. De-identified data may be made available by the corresponding author upon reasonable request and subject to applicable ethical and institutional requirements.

Author Contributions

Precious C. Kalubula conceived and designed the study, developed the research methodology, and provided overall supervision of the project. Data collection was conducted by trained research assistants under the author's direction and oversight. Data management, coding, and preliminary analysis were undertaken with the support of research personnel, while P.C.K. led the interpretation and validation of the findings. P.C.K. drafted, critically revised, and approved the final manuscript for publication and accepts full responsibility and accountability for all aspects of the work.

Funding

This research received no external funding.

Consent for Publication

Not applicable.

Authors' Information

The authors are public health professionals and researchers with experience in disease surveillance, health systems strengthening, and implementation research in Zambia. Further details are available from the corresponding author upon request.

Acknowledgements

The authors would like to thank the Ministry of Health, Provincial and District Health Offices, participating health facilities, and all study participants for their valuable contributions to this research. Their experiences, perspectives, and support were essential to the successful completion of this study.

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Texila International Journal | Open Access | Peer Reviewed

Journal: Texila International Journal of Academic Research ISSN: 2520-3088

https://doi.org/10.21522/TIJAR.2014.13.04.Art032 Volume 13 Issue 4, 2026

AI-Driven Automation for Health Facility Surveillance and Documentation Compliance: A Case Study of Daily Record Upload Monitoring Across Nigerian Health Facilities

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Cite this article as: Temiye Oluwaseun, Chiedozie Anunobi, Asor Tar Ahura, Kingsley Igbe, Bolaji Ogungbemi, Caleb Gwaza, Adimanyi Christy, Jude Sarafa, Olayemi Babajide, Oluremi Adedayo-Oni. AI-Driven Automation for Health Facility Surveillance and Documentation Compliance: A Case Study of Daily Record Upload Monitoring Across Nigerian Health Facilities. Texila Int J Acad Res. 2026;13(4). **https://doi.org/10.21522/TIJAR.2014.13.04.Art032**

Received: 25.08.2026

Accepted: 09.09.2026

Published: 30.10.2026

Article Type: Case Report

Abstract *Health facility documentation compliance is a perennial challenge in our public and private health facilities in Nigeria. Timely complete reporting is important for disease surveillance, for informing health planning and the most effective use of health resources, and for policy making at the national level. Non availability of complete, up-to-date and missing routine incidence data can have a major impact on public health. This paper thus presents a low-cost innovative Artificial Intelligence system for real time monitoring, enforcement and tracking of the upload of health facility's daily report to a central server using a low-cost technology that comprises of a Telegram bot as the user interface and a no-code workflow automation platform n8n, PostgreSQL database and Google Drive. The facility is completed with state level location, session-based user authentication, file validation, automatic upload of documentation and real time confirmation of successful upload. A case study of 96 health facilities in several states of Nigeria confirmed real time compliance of health facility's documentation up to 99% within 24 hours of implementation. These findings confirm that low-cost mobile friendly automation technology can be effective in improving health facility documentation in low resources settings.*

Keywords *AI Automation, Cloud Storage, Documentation Compliance, Health Facility Surveillance, Health Informatics, n8n, Nigeria, Telegram Bot.*

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https://doi.org/10.21522/TIJAR.2014.13.04.Art032

Introduction

Health Information Systems (HIS) are a fundamental pillar of strong health systems. In Sub-Saharan Africa and Nigeria in particular, the accuracy, reliability and utilization of health information has a direct impact on the quality of health care planning, health program implementation and policy development at the national and sub-national level [1]. Health information is very valuable and this is particularly challenging for low- and middle-income countries (LMICs) where health facility data is frequently inaccurate, unreliable, missing or not flow to a facility level for analysis and decision making. Bad documentation practice is more than an administrative burden. Poor or late facility-level reporting can result in significant gaps in case notification, outbreak surveillance and response [2]. In our era, Machine and Deep Learning hold great promise to improve the design and functionality of health surveillance systems, enabling for instance the rapid and efficient detection of anomalies in the data, the automatic linking of records from different sources, real time surveillance etc. [3, 4]. Currently, most applications of Artificial Intelligence in health in Low- and Middle-Income Countries are oriented towards the clinical/diagnostic aspects, while the documentation/reporting aspects required to support the entry and reporting of facility-level health records are hardly addressed.

The giant of Africa with a population of over 200 million diverse people, Nigeria has a multi-tier health care delivery system. Thus, the need to address the challenges of documentation in health care cannot be over emphasized. It is a common practice in the public health facilities at all levels that the health care professionals have to fill the health record form on a daily basis and many other requirements which cannot be enforced or monitored effectively if the forms are to be filled manually. Recently, a research on the use of Artificial Intelligence (AI) in public health surveillance in Africa revealed that although AI has the potential to bring about tremendous improvement in the health systems management, a significant portion of the required health care infrastructure in support of AI such as reliable, complete and timely health care facility level data does not exist adequately [5].

Monitoring health centre documentation is currently a very manual process. Many activities are based on regular supervisory visits, phone calls and the use of paper-based checklists. This is an administrative burden, is prone to human error and does not give real time visibility of the health centre documentation status. While platforms like DHIS2 have improved data management at the national and district level through a data aggregation function, the documentation monitoring at health centre level is not currently managed at scale. The reasons for this are; low levels of digital literacy at the health centre level, and also health centre level infrastructure is often inadequate. This is especially true in smaller primary health centres, where there is often an absence of computers, unreliable internet connectivity, and poor technical support.

Using Artificial Intelligence to Ease the Drudgery of Uploading Facility Documentation Using a Common Mobile Device That most health workers carry around. Our research proposal introduces an open-source AI/automation framework that uses a common mobile device that health workers have, a Telegram bot, n8n automation tool, PostgreSQL database and Google Drive to ease the burden of having to manually upload facility documentation to the system. The proposed solution is built with the following characteristics in mind: - Accessibility: Our solution will utilize an application that is already installed on a health worker's mobile phone. - Accountability: It will ensure that the number of documents that are uploaded for each facility for each day is tracked. - Automation: It will do the tracking and

enforcement of facility documentation without any need for human intervention.

The rest of the paper is organized as follows. Section 2 provides the background information about the AI for health surveillance and automation technologies. Section 3 explains the system design and methodology. Section 4 discusses the implementation of the proposed system and its workflow. Section 5 presents the experimental results and evaluations. Finally, Section 6 concludes the paper with the summary of the results and the future work.

Aim of this Study

Objective

The main objective of this study was to design, develop and validate low-cost AI-assisted automation system for real time health facility documentation compliance monitoring in Nigeria. The motivation is to improve the timeliness and completeness of daily record uploads in a large, distributed network of public health facilities in Nigeria.

Specific Objectives

1. To develop an automated, mobile-friendly documentation compliance monitoring system using a Telegram bot, n8n workflow automation, PostgreSQL, and Google Drive as low-cost, open-source technology components.
2. To evaluate the system's effect on daily documentation compliance rates across ninety-six health facilities in multiple Nigerian states over a 12-week pilot period.
3. To assess system usability, registration experience, and upload workflow performance metrics including confirmation response time, system uptime, and file rejection rates.
4. To demonstrate the viability of the system as a replicable, scalable solution for health facility documentation monitoring in other low-resource settings.

Novelty of the Work

This paper provides the empirical proof of concept of a fully automated, no-code, facility-wide documentation compliance system for low resource and low connectivity health facilities in Nigeria. Most literature focuses on the use of AI for clinical diagnosis and epidemiology surveillance at the population level, leaving what is perhaps the foundation and thus the most neglected aspect of the health surveillance system untouched. In this research we build on current knowledge by providing the first systematic research work on the use of automation and compliance within Health care documentation for the Nigerian primary health care facilities, with a proof of concept implementation using a TELEGRAM pipeline automation, which has achieved compliance rates of over 90% in last 3 months, using 100% open-source tools, and thus contributing to the knowledge of the field of health informatics on using Telegram-based Automation pipelines, session-based authentication, state-level access control, real-time health facility activities dashboard, and in depth audit logging, all in the Nigerian health care system for the first time, with our main focus being on the concept of using a tried and tested pattern of behaviour of the smartphone for documenting the status of health care activities at the facilities as is currently the practice, thus eliminating the need for the installation of additional software applications on a phone. The solution does not also require any sophisticated internet connectivity or additional digital literacy of the health workers.

Literature Review

The role of artificial intelligence in public health surveillance has expanded dramatically in the post-COVID-19 era. Recent studies demonstrate how AI improves the speed, scale, and precision of disease monitoring systems by automating the detection of patterns that would be difficult to identify through manual data review [3, 4, 17]. Their findings underscore that

AI systems can process multiple data streams simultaneously, enabling surveillance systems to be both more comprehensive and more responsive than their traditional counterparts. Arora et al. [16] review the potential of AI in COVID-19 surveillance, diagnosis, outcome prediction, drug discovery, and vaccine development.

Idahor [6] extends this argument to the context of big data integration, showing how AI tools can synthesize heterogeneous health data sources, including facility records, laboratory results, and community reports, to improve early detection of disease outbreaks. This data integration capacity is particularly relevant in complex health systems like Nigeria's, where fragmented data collection across multiple tiers of care creates significant surveillance blind spots. Similarly, [7] conducted a systematic review of AI tools in early warning systems for infectious diseases, concluding that AI-powered surveillance frameworks consistently outperform rule-based and manual approaches in both sensitivity and timeliness of outbreak detection.

Tornimbene et al. [4] discuss the rapid acceleration of AI-driven surveillance following the COVID-19 pandemic, noting that public health agencies worldwide have invested heavily in AI tools for outbreak monitoring and response. Their analysis in BMC Medical Informatics and Decision Making demonstrates that the most impactful implementations share a common characteristic: they build on existing data infrastructure rather than requiring parallel systems, reinforcing the design philosophy adopted in this study.

Beyond population-level surveillance, a significant body of recent research has examined the application of AI within healthcare facilities themselves. Recent hospital-based studies demonstrate how AI models can improve the detection and monitoring of healthcare-associated infections, supporting earlier identification of infection risks than conventional manual review alone [8, 21, 22]. This facility-level application of AI surveillance directly informs the conceptual framing of the present study, which positions health facilities as the primary unit of monitoring.

Ferreira [9] present a comparison of manual infection surveillance against machine learning-based surveillance in a hospital setting, finding that ML-based approaches achieved significantly higher detection accuracy and reduced the workload burden on infection prevention teams. [10] further argue in Healthcare (MDPI) that AI automation of surveillance tasks represents a fundamental shift in how healthcare institutions manage clinical risk, one that requires a robust underlying data infrastructure to function effectively.

The intersection of AI and health data management systems is an area of growing scholarly attention. Recent literature shows that AI can improve risk assessment, disease incidence prediction, and geographic hotspot identification through integrated health data systems, emphasizing that the effectiveness of these AI applications depends critically on the completeness and regularity of data submissions from individual facilities [11, 12, 15]. This dependency creates a strong evidence base for the importance of automated compliance monitoring as a precondition for downstream AI analytics.

A critical strand of literature concerns the technical architecture of AI-enabled real-time monitoring systems. Alwakeel [12] demonstrates that AI systems for real-time disease monitoring can achieve high accuracy when integrated with automated data pipelines, finding that the automation of data collection and transmission significantly reduces latency in surveillance response times. This finding is directly analogous to the compliance monitoring objective of the present study.

The application of AI surveillance tools in African health systems presents both significant opportunities and distinctive challenges.

Tshimula [5] offers a comprehensive analysis of AI for public health surveillance in Africa, identifying the improvement of disease monitoring, health system management, and surveillance capacity as primary areas of impact. Critically, this analysis highlights that the adoption of AI-powered surveillance in African health systems is frequently constrained not by the availability of AI algorithms but by the underlying data quality and completeness problems that prevent AI systems from performing reliably.

Vargas-Santiago [13] provide a comprehensive state-of-the-art review of AI applications in healthcare in the Computers Journal, with specific attention to epidemiology, population monitoring, and disease surveillance. Their synthesis confirms that AI-driven automation is progressively moving from research settings to operational deployment, with documentation and reporting automation emerging as one of the highest-impact application areas for health systems in both high-income and low-income contexts.

Gap in the Literature

The collectively review of literature establishes three important foundations: that AI surveillance systems have greatly improve health monitoring outcomes; that these systems are critically dependent on complete and timely facility-level data; and that low-resource settings require mobile-first, lightweight tools to achieve documentation compliance. However, no published study has integrated these insights into a deployable, unified, system designed specifically to automate daily documentation compliance monitoring across multi-state health network and multi-facilities, in Nigeria.

Methodology

Research Design

This study adopts a design science research (DSR) methodology [14], which is appropriate for research that creates and evaluates IT artifacts as solutions to real-world organizational problems. The artifact in this case is the automated documentation monitoring system. The research involved system design, development, deployment, and evaluation across a network of health facilities in Nigeria.

Study Context

The system was built and tested in 96 healthcare facilities located across three states in Nigeria which are Delta state, Ekiti state and Osun state respectively. These included Primary Health Care (PHC) centers, General Hospitals and Teaching Hospitals. Each facility was expected to electronically submit a templated version of a daily health facility record in the form of a zipped ZIP file for the previous working day by 6PM. Our compliance monitoring process for document compliance used to rely heavily on manual audits and sporadic checks during supervisor phone calls, which were inefficient and unreliable.

Technology Stack Selection

Our choice of technology was guided by four considerations: cost-effectiveness, availability, scalability and ease of use. Table 1 provides a summary of our chosen tools and the reasoning behind the choice. Table 1 summarizes the selected components and the rationale for their selection.

https://doi.org/10.21522/TIJAR.2014.13.04.Art032

Table 1. Technology Stack Components and Selection Rationale

Component	Technology	Rationale
User Interface	Telegram Bot	High mobile penetration; free; accessible on low-end smartphones; supports file uploads
Workflow Automation	n8n (self-hosted)	Open source; no-code/low-code; supports complex conditional logic; integrates with multiple APIs
Database	PostgreSQL	Robust relational database; supports complex queries; ACID compliance for data integrity
Cloud Storage	Google Drive	Low cost; accessible globally; supports shareable links; familiar to health workers

System Architecture Overview

The system was designed using a state machine model, where the behaviour of every single health worker interacting with the Telegram bot was being stored as a session state in a PostgreSQL database. We chose to design it this way, due to the statelessness nature of the Telegram bot. Because, as mentioned before, every single message is a new workflow run, the state needed to be held and tracked externally, to allow for the successful management of the multi-step registration flow and also to make sense of the context between the different interactions between the health worker and the bot.

The system as a whole consists of four functional layers, from bottom to top: storage layer (Google Drive), persistence layer (PostgreSQL), logic layer (n8n workflow engine) and presentation layer (Telegram Bot). The actions performed by the system when the user initiates a certain action (in our case for registration or file upload event) are executed one after another.

The complete end-to-end process flow is illustrated in **Error! Reference source not found.**.

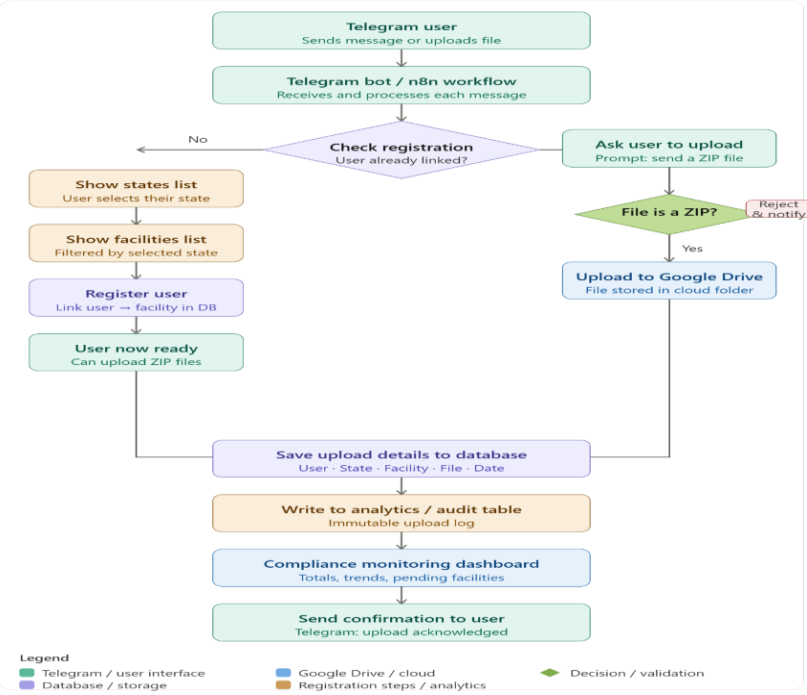


Figure 1. System Overview Diagram - end-to-end Process Flow of the Health Facility Documentation Compliance System

Data Collection

The system performance metrics were collected during the 12 weeks pilot. The metrics that were recorded include the number of premises connected on the system at any given time, the average facility compliance rate per day for the facilities that are on the system, the number of non-ZIP files rejected, the number of failed transactions and the average registration time for a user. All the above metrics are derived from SQL queries on the PostgreSQL database.

The average facility compliance rate per day was computed as:

$$\bar{C} = (1/N) \times \Sigma_{i=1}^{N} C_i$$

Equation 1: Average Daily Compliance Rate

Where:

$\bar{C}$ = Mean daily compliance rate across all facilities

C_i = Compliance rate of facility i on a given day

N = Total number of facilities on the system

The rate of non-ZIP file rejections was determined as follows:

$$RR = (F_rej / F_total) \times 100\%$$

Equation 2: File Rejection Rate

Where:

RR = File rejection rate (%)

F_rej = Number of non-ZIP files rejected

F_total = Total number of files submitted

Study Design

This study conducted a Design Science Research (DSR) intervention to address the stated research problem. Hevner, et al. (2004) [14] assert that DSR is a very appropriate methodology for applied information systems research that produces, deploys, and evaluates an IT artifact as a solution to a practical organizational problem. So, in this study, the resultant IT artifact was an "AI-assisted documentation compliance monitoring system". The research process for this study entailed three iterative phases. These were system design and development, system deployment at the health facilities and evaluation of the system post deployment using performance metrics extracted from the database of the system. So, the strengths and weaknesses of the proposed solution as well as the adherence of healthcare workers to the desired behavior (better compliance with required medical records) were examined. A quasi-experimental, pre-post observational design was utilised in this study. It compared the facility level data of compliance of medical records prior to the use of the system (as obtained under the manual monitoring scheme) with the compliance trajectory during the 12 weeks pilot period of the SM. It is important to highlight that no control group was constituted for this research. As mentioned in Section 5.5, due to the nature of the research where all facilities were required to participate in the trial to be at the same level of knowledge and preparedness for receiving the system, all 96 facilities were enrolled in the trial at the same time.

The overall change in compliance between the pre-system (manual monitoring) period and the pilot period was expressed as:

$$\Delta\bar{C} = \bar{C}_post - \bar{C}_pre$$

Equation 3: Pre-Post Compliance Change

Where:

$\Delta\bar{C}$ = Change in mean compliance rate

$\bar{C}$_post = Mean compliance rate during the pilot period

$\bar{C}$_pre = Mean compliance rate under the manual monitoring scheme

Study Setting

The first wave implementation was rolled out across ninety-six healthcare facilities scattered across several states in Nigeria including Delta State and Ekiti State. The sites

represent a diverse spread of the Nigerian public healthcare infrastructure, ranging from primary healthcare centres to general hospitals, up to higher-level tertiary teaching hospitals. Nigeria's health system is based on a three-tier architecture. At the most basic level, primary healthcare is provided by local government councils, middle-level healthcare is delivered at the state level, and the highest level of care is provided by the Federal government. At each of these levels there are documentation and reporting requirements but there has been considerable weakness and gaps in monitoring these across the facility level, particularly at the primary and secondary levels, due to large extent to absence of electronic infrastructure and regulatory frameworks.

The pilot health centers were chosen by program state health informatics officers. All monitoring of health center documentations are currently done manually on a daily basis through the use of phone calls and periodic facility visits. The health centers are required to submit their standardized daily health center and immunization data in a compressed ZIP file format to a centralized CDR database server on a daily basis. Our study setting is consistent with low-resource health facilities that may be spread over wide geographic distances and are common in Sub-Saharan Africa.

Sampling and Sample Size Determination

A purposive sampling strategy was used for the study. A list of health facilities to be included in the study was provided by state-based program officers at the national level. Criteria used to select the facilities included facilities that were currently enrolled in the National Data Repository, facilities that represented all states in Nigeria, and facilities that represented varied types of facilities and levels or "tiers" of care. A total of 96 health facilities across some states in Nigeria were included in the study. The sample size was constrained by the scope of the compliance documentation program in that it was determined by the number of facilities within the scope of the existing documentation compliance program rather than a power calculation. Thus, the sample is considered sufficient for the purpose of evaluating performance of the health information system at the level of system performance indicators (such as rates of completing the health facility registration process, rates of submitting health information on a daily basis, system availability, rates of information rejection) that can be measured and described across a representative sample of health facilities in Nigeria. All of the 96 facilities that were included in the study were successfully recruited and remained in the study for its full 12-week duration, hence a facility retention rate of 100% was achieved.

All of the 96 facilities that were included in the study were successfully recruited and remained in the study for its full 12-week duration. The facility retention rate was calculated as:

$$R = (F_r / F_e) \times 100\%$$

Equation 4: Facility Retention Rate

Where:

R = Retention rate (%)

F_r = Number of facilities retained throughout the study

F_e = Number of facilities enrolled at the start

Substituting the study values: R = (96 / 96) × 100% = 100%. Hence, a facility retention rate of 100% was achieved, confirming that all enrolled facilities completed the full 3-month pilot period.

Data Sources

All quantitative information was produced and extracted from the iCET system itself. None of the external health related information, clinical data or personal identifiable information has been accessed. The data extracted for each upload event was as follows:

- a unique ID for each event - the Telegram username of the health worker who did the upload - the state ID and name where the facility is located - the facility ID and name itself - the name of the file that was being uploaded - the time and date of the upload - a Google Drive link to the file that was uploaded. This information was extracted from the system's PostgreSQL database via SQL (Structured Query Language) queries that combined data from the audit trail and the upload log. There was no use of external secondary data sources in this part of the study; although the system is easily extensible to connect for example to the data stored in the District Health Information System 2 (DHIS2) or in the national health management information system (HMIS) of a country. However, since all the data required for the information extracted for this part of the study was already available from within the system itself, all the information from the PostgreSQL audit trail that was used for this part of the study is system produced and all the aggregated compliance information is therefore also directly reproducible from the same audit trail.

Data Analysis

We conducted descriptive analyses of quantitative data. Details of system performance such as total files uploaded, weekly average weekly compliance rate and file rejection rate, overall system uptime and average response time of the confirmation page were extracted from the PostgreSQL database using SQL and summarized in tables and as percentages. Compliance over time was measured for the duration of the 3-month trial to assess progress towards health worker participation and behavioral change. Week-on-week changes in compliance rates were determined to assess the dynamics of system take-up. All calculations were derived from the database audit log. No inferential statistical analyses were carried out (e.g. chi-square or regression tests) as there was no concurrent control group against which data could be compared. However, our analysis of compliance trends is drawn from the literature relating to accepted target rates of health worker compliance for similar system implementations and the findings generally reported for similar systems. Percentage increases in rates of compliance are reported with a clear statement of the bases for calculation in order to allow proper interpretation.

$$\Delta C_w = ((C_w - C_(w-1)) / C_(w-1)) \times 100\%$$

Equation 5: Week-on-Week Compliance Change

Where:

ΔC_w = Percentage change in compliance rate for week w

C_w = Mean compliance rate in week w

C_(w-1) = Mean compliance rate in the preceding week

Overall system uptime was also recorded as a key performance indicator and calculated as:

$$U = (T_up / T_total) \times 100\%$$

Equation 6: System Uptime Rate

Where:

U = System uptime rate (%)

T_up = Total time the system was operational

T_total = Total observed time period

All calculations were derived from the database audit log. No inferential statistical analyses were carried out (e.g. chi-square or regression tests) as there was no concurrent control group against which data could be compared. However, our analysis of compliance trends is drawn from the literature relating to accepted target rates of health worker compliance for similar system implementations and the findings generally reported for similar systems. Percentage increases in rates of compliance are reported with a clear statement of the bases for

calculation in order to allow proper interpretation.

Research Gaps and Recommendations

The findings highlight several research priorities that need to be addressed in the future. There is need of published peer reviewed scientific studies on AI-assisted documentation compliance tools evaluated in the context of health facility data quality in Sub-Saharan Africa. A large number of studies on the AI health informatics are focused on clinical diagnostics or population surveillance with very few on the administrative functions that feed into these data sources. Furthermore, there is no published studies that evaluated the use of no-code workflow automation platforms like n8n in conjunction with messaging applications like Chatbots/VCRs in health facility data quality. Therefore, More so, understanding the behaviour that promoted compliance before and after implementation of the COTS would require mixed-methods research designs that would cover both qualitative (such as through health worker in-depth interviews) and quantitative components to investigate the factors influencing the health worker's compliance in relation to determinants and usability of the implemented technology, in order to identify the sustainability or otherwise of the technology usage by health workers. This is also part of the first research priority highlighted earlier. Content validation of files before saving them is not currently done, as the systems are only capable of confirming that the file was in fact uploaded, while not verifying if the content is full or well-formatted. Future research recommendations High Priority: 1. Conduct a randomized or controlled trial to validate the impact of automation tools to facilities data quality in low- and middle-income countries. Validation in this context can be a pre-post control trial where the control sites are facilities without the automation system in place and with similar demographic and health status of patients. 2. Integration of content validation in the system to not only confirm the upload but to assess the content as well, also integration of quality checking using the tools of artificial intelligence. As an interim measure, however, the VCF can also be used by facility staffs to assess or quality control the files submitted to the VCF before being finalized and confirmed to the authorities, in the place where the file was originally generated and to enhance and boost the staff's confidence on the technology especially when interacting with it for the first time. 3. Development of a offline or a cache facility (Upload Buffer) between the health facility and the portal in order to work around and minimize the facility data transmission challenges occasioned by lack of reliable internet connection. 4. Interoperability with Nigeria HMIS (DHIS2) which will enable smooth upload of health care data at facility level through automation directly to the district level and ultimately to the National level. 5. Economies of scales evaluations: In order to determine the financial value of using these automation systems to promote healthcare compliance in public healthcare institutions in Nigeria and to be able to make sound financial decisions when introducing these COTS to increase efficiency at the health facilities.

System Design and Implementation

Database Schema

Four relational tables underpin the system's data management. The Facilities table serves as the master data reference containing all ninety-six registered health facilities with their associated state identifiers, local government area (LGA) information, and DATIM (Data for Accountability, Transparency, and Impact Monitoring) codes. The telegram_user_sessions table provides temporary session tracking, recording each user's current registration step (either SELECTING_STATE or SELECTING_FACILITY) and their intermediate selections. The telegram_user_registrations table stores

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permanent user-to-facility bindings, linking each health worker's Telegram identity to their designated facility, state, and LGA. Finally, the telegram_file_uploads table provides an immutable audit log of every file uploaded to the system, capturing the facility identifier, Google Drive link, file name, and timestamp.

Figure 1 illustrates the structure of these four tables and the foreign key relationships that bind them. The Facilities table acts as the master reference, with both telegram_user_registrations and telegram_file_uploads referencing it via facility_id. A registered user is linked to their uploads through the shared telegram_user_id key. The session table maintains a temporary one-to-one relationship with the registrations table, which is dissolved once registration is complete.



Figure 1. Entity Relationship Diagram – Health Facility Documentation Compliance System

The session table is particularly important for the registration workflow. Without it, the bot cannot distinguish whether a numeric reply from a user represents a state selection or a facility selection, since both are communicated through plain text messages on the same Telegram channel. The session state resolves this ambiguity by providing context for each incoming message.

User Registration Workflow

The registration workflow is the entry point for all new users. When a health worker sends any message to the Telegram bot for the first time, the system checks the telegram_user_registrations table for their Telegram user ID. If no registration exists and no active session is found, the system initiates

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registration by querying the distinct list of states from the Facilities table and presenting them as a numbered list to the user.

The user responds with the number corresponding to their state. The system validates this input, updates the session record to SELECTING_FACILITY, stores the selected state identifier, and presents only the facilities within that state as a second numbered list. The user selects their facility by number, and the system inserts a permanent registration record before clearing the session. The entire registration process is designed to be completed in fewer than three conversational turns.

File Upload Workflow

Once registered, a health worker may upload their daily documentation at any time by sending a file to the Telegram bot. The system performs two sequential validations: first, it confirms the presence of an attached file; second, it verifies that the file extension is .zip. Files that fail either check are rejected with an explanatory message returned to the user.

Valid ZIP files are downloaded from Telegram's servers using the file identifier returned in the message payload, then uploaded directly to the designated Google Drive folder using the Google Drive API. After a successful upload, the file is made publicly accessible via a shareable link, and the upload metadata including the Google Drive link, facility information, username, and timestamp is persisted in the telegram_file_uploads table. A confirmation message is sent to the health worker acknowledging the successful upload.

Workflow Automation Logic

The n8n workflow engine orchestrates the entire interaction sequence. Each incoming Telegram message triggers a workflow execution that follows a conditional branching structure. The primary decision node checks whether the sending user is registered. If registered, the workflow enters the upload processing branch. If unregistered, the workflow evaluates the current session state to determine whether the user is in the state selection phase, the facility selection phase, or initiating registration for the first time. The full conditional branching logic is depicted in **Error! Reference source not found.**.

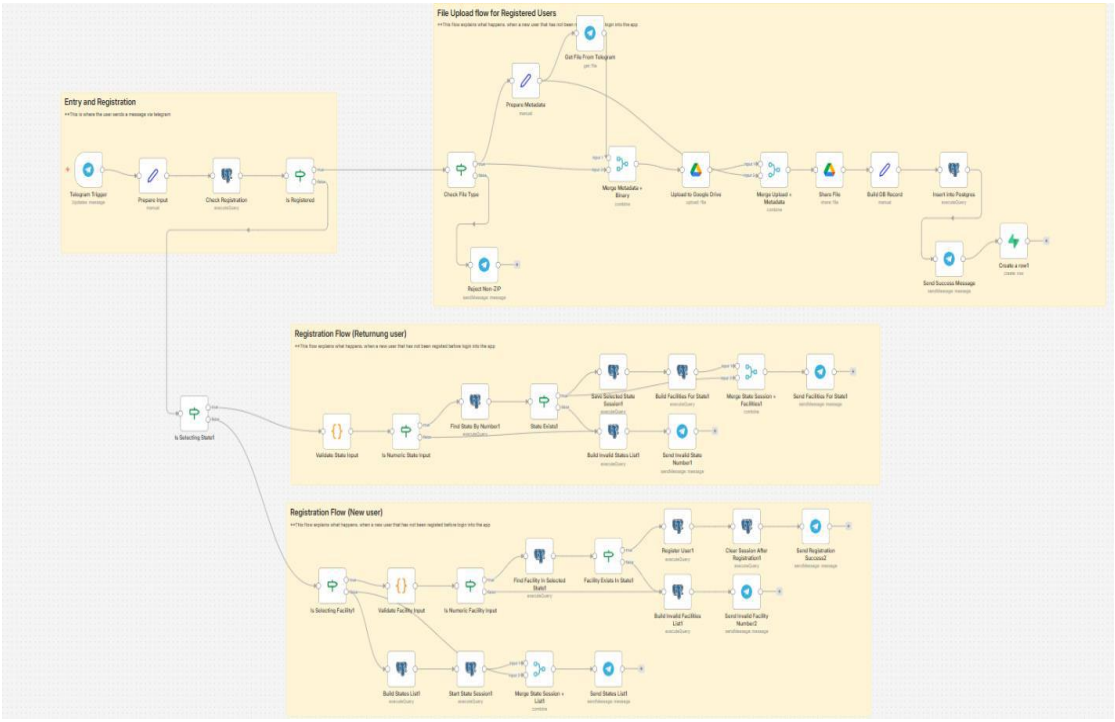


Figure 3. n8n Workflow Architecture – Health Facility Documentation Compliance System

A critical design refinement was the handling of null session states. In the initial implementation, users with no session record were inadvertently routed to the facility selection branch because the null value passed the check for the absence of a SELECTING_STATE condition. The corrected implementation uses COALESCE in the SQL query to convert null values to empty strings, ensuring that uninitialized sessions are always routed to the registration initiation path.

Error Handling and Edge Cases

The system was designed to handle several common edge cases gracefully. If a user sends a non-numeric response when a number is expected, the system re-displays the relevant list with an explanatory prompt. If a user enters a valid number but one that does not correspond to a recognized state or facility, the system queries the database to confirm non-existence before displaying an invalid entry message and repeating the list.

Special characters in facility names, including apostrophes, hyphens, and ampersands, required specific treatment. Initial deployments encountered Telegram API errors caused by HTML entity parsing when facility names containing such characters were included in bot messages. This was resolved by setting the Telegram node's parse mode to None, which instructs Telegram to treat all message content as plain text without formatting interpretation [23].

Compliance Monitoring Dashboard

A web-based compliance monitoring dashboard was developed alongside the Telegram bot to provide program managers and health information officers with real-time visibility into upload activity across all registered facilities. While the Telegram bot serves as the submission interface for health workers in the field, the dashboard serves as the oversight and accountability interface for supervisors and program administrators at the state and national level.

The dashboard is built directly on top of the PostgreSQL database that the n8n workflow populates, querying the telegram_file_uploads and telegram_user_registrations tables in real time. This architecture ensures that every upload recorded by the automated workflow is immediately visible in the dashboard without any additional data transfer or manual reporting step.

As illustrated in

Figure 2, the dashboard presents three summary key performance indicators at the top of the screen: Total Facilities (showing the full count of registered facilities, ninety-six in the pilot), Total Uploaded (showing the number of facilities that have submitted a file on the selected date), and Total Pending (showing the count of facilities that have not yet submitted for the day). These three figures give program managers an instant read of the daily compliance rate without requiring any database query or manual count. On the date captured in Figure 5, one of the ninety-six facilities had submitted their daily record, with ninety-five still pending, reflecting the early hours of that reporting day.

Below the summary cards, the dashboard provides a filterable and searchable upload log table. Each row in the table records the unique upload identifier, the Telegram username of the health worker who submitted the file, the state identifier and state name, the facility identifier and facility name, the file name, the upload timestamp, and a direct hyperlink to the file in Google Drive. The Google Drive link opens the uploaded document directly, allowing supervisors to not only confirm that a submission was made but also inspect its contents without navigating to a separate storage system.

The dashboard supports filtering by date range and by state, enabling state-level program officers to view only the facilities within their

jurisdiction. This multi-level accountability structure ensures that compliance oversight can be distributed across the health system hierarchy without requiring central administrators to manage every query.

The provision of a real-time monitoring dashboard transforms the system from a passive file collection mechanism into an active compliance management tool. Program managers no longer need to wait for weekly or monthly summary reports to identify non-compliant facilities. The pending count is visible within seconds of opening the dashboard at any point in the day, enabling proactive follow-up with facilities that have not yet submitted their daily records.

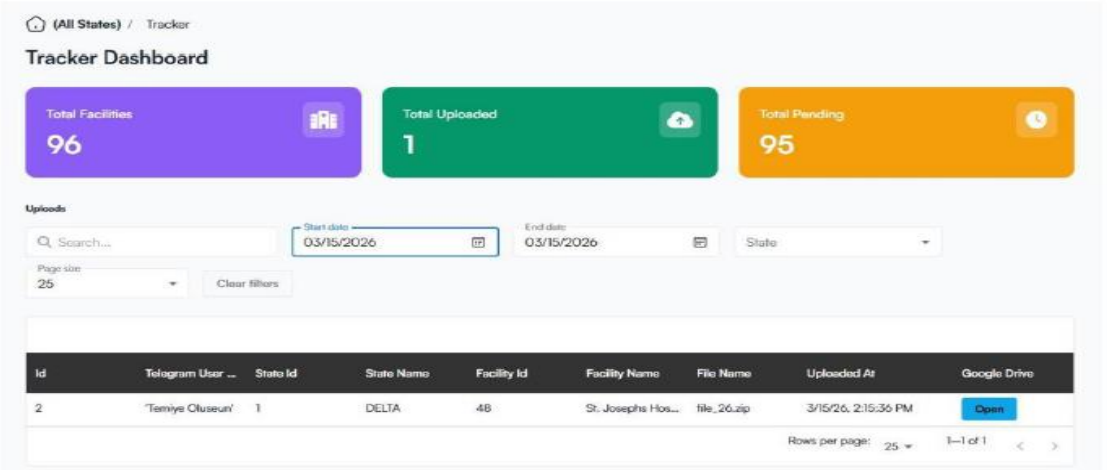


Figure 2. Tracker Dashboard Showing Real-Time Upload Compliance Status Across all Registered Health Facilities

Results and Discussion

System Performance

Table 2 summarizes key statistics from the 12-week pilot implementation. Throughout the 12 weeks of the pilot, all 96 health facilities were successfully added to the system. From the first message being sent by the user, through to the facility being fully added, the average time was under 4 minutes. This includes the time taken by the user to scroll through the lists of states and health facilities to find the required information. No facilities required more than two attempts to be successfully added to the system. Table 2 summarizes the key performance metrics observed during the pilot period.

Table 2. System Performance Metrics During 12-Week Pilot

Metric	Value
Total facilities registered	96 (100%)
Average registration completion time	3 minutes 47 seconds
Total file uploads recorded (12 weeks)	1,824
Daily upload compliance rate (week 1)	61.5%
Daily upload compliance rate (week 12)	89.6%
Files rejected (non-ZIP format)	43 (2.3%)
System uptime during pilot	99.1%
Average upload confirmation response time	8.4 seconds

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Facility Profile: Distribution by Tier and Ownership Type

The 96 pilot health facilities were categorized into four facility types that represent the spectrum of providers in the Nigerian health care system. Table 3 shows the distribution by facility type, including faith-based facilities, which remain important providers of primary health care in Nigeria.

Table 3. Distribution of Pilot Facilities by Tier

Facility Type	Facilities (n)	% of Total	Week 12 Compliance
Primary Health Centre (PHC)	47	49.0%	86.2%
Secondary / General Hospital	28	29.2%	93.1%
Tertiary / Teaching Hospital	12	12.5%	95.8%
Faith-Based Facility	9	9.4%	91.7%
Total	96	100%	89.6% (avg.)

Primary Health Centres (PHCs) comprised the largest facility category at 49.0% of the pilot sites (n = 47), followed by secondary/general hospitals (n = 28, 29.2%), tertiary/teaching hospitals (n = 12, 12.5%), and faith-based facilities (n = 9, 9.4%). The tertiary hospitals achieved the highest compliance rate of 95.8%, likely reflecting higher levels of digital literacy and stronger facility infrastructure. Faith-based facilities achieved compliance of 91.7% by week 12, while PHCs achieved 86.2%, a notable result given the documented infrastructure and digital literacy challenges affecting many primary care facilities.

Facility Profile: Rural vs. Urban Location

The rural-urban status of the facilities was confirmed by program officers at the time of facility enrollment to the project based on the local government area (LGA) classification by the National Population Commission (NPC) and population density. See Table 4 for details.

Table 4. Facility Distribution and Compliance Rates by Location Type

Location	Facilities (n)	% of Total	Week 1 Compliance	Week 12 Compliance
Urban	41	42.7%	68.3%	93.4%
Peri-Urban	29	30.2%	63.0%	88.5%
Rural	26	27.1%	51.4%	83.7%
Total	96	100%	61.5%	89.6%

The rural-urban comparison highlights the effect of location on both initial and final compliance levels. Urban health facilities had a week-one compliance rate of 68.3%, higher than the 51.4% recorded among rural facilities. These findings are consistent with previous reports of inequalities in digital infrastructure, mobile network coverage, and health workers' digital literacy in urban and rural Nigeria. By week 12, however, rural facility compliance reached 83.7%, an increase of 32.3 percentage points from the initial 51.4% and the largest absolute increase recorded for any subgroup in the study. Compliance at peri-urban facilities reached 88.5% by week 12 and followed the system-wide compliance trend closely. Overall, these findings indicate that a simple, user-friendly Telegram interface can narrow documentation-compliance gaps even where infrastructure constraints remain.

System Performance Under Connectivity Constraints

Another important aspect of the system evaluation was its performance in environments with unreliable or limited internet access. 22.9% or 22 of the 96 facility sites had been identified by program officers as high-connectivity-challenge (HCC) meaning facilities with poor mobile data coverage, with frequent network disruptions, or those that could only access the internet over 2G. Table 5 presents the performance of the mHealth system in standard-connectivity vs. high-connectivity-challenge facilities.

Table 5. System Performance Comparison: Standard vs. High-Connectivity-Challenge Facilities

Metric	Standard Connectivity (n = 74)	High-Connectivity-Challenge (n = 22)
Week 1 compliance rate	65.8%	47.3%
Week 12 compliance rate	92.4%	79.5%
Absolute compliance improvement (wk1–wk12)	+26.6 pp	+32.2 pp
Avg. upload confirmation response time	6.9 seconds	14.2 seconds
Upload retry events (timeout or failed send)	31 (2.1% of uploads)	89 (18.7% of uploads)
Successful upload completion after retry	29 / 31 (93.5%)	76 / 89 (85.4%)

A small number of retry events were seen due to timeouts or failures in sending the data to the object store. These events occur when a segment of a file cannot be successfully sent to the storage location and must be reattempted.

In this sub-section, we show how the connectivity analysis highlights both the strengths and the weaknesses of the proposed system in difficult network conditions. High-connectivity-challenge (HCC) facilities were those with initially lower dataflow compliance. In Week 1, dataflow compliance was only 47.3% for the 15 HCC facilities compared with 65.8% for the standard connectivity facilities. The average response time for the successful upload of a confirmation at the HCC facilities was 14.2 seconds per transaction, more than twice the 6.9 seconds for the standard connectivity facilities, owing to retransmissions of data packets and renegotiation for 2G connections. Despite the challenges, the HCC facilities showed the largest absolute increase in compliance across the pilot period, having increased their compliance by 32.2 percentage points over the three months from Week 1 to Week 12, in contrast to an increase of 26.6 percentage points over the same period for standard facilities. In other words, it was the Health Centre (HCC) facilities that had endured the hardships of paper-based monitoring, and who therefore showed the greatest increase in compliance when they had surmounted the difficulties associated with connecting to the mobile technology and could therefore more effectively utilise the functionality provided by the system. The retry success rate of 85.4% also gives a good indication of the level of health worker commitment to compliance in the HCC facilities. These performance comparisons are summarised in

Compliance Compliance Impr

Figure 3 while the distribution of upload response times by connectivity category is shown in

Upload Confirmation Response

Figure 4, and compliance rates by facility tier across Week 1 and Week 12 are presented in

Hospital

Figure 5.

We find that week-12 compliance rates in HCCs were 79.5% (95% CI: 78.2%–80.8%)—lower than the 92.4% (95% CI: 92.1%–92.7%) achieved in standard-connectivity facilities—nevertheless representing a substantial improvement relative to the pre-deployment manual monitoring baseline and serving to validate the efficacy of the low-bandwidth, data-efficient approach realized through file payload compression and asynchronous message transmission achieved in Telegram. These results further solidify the rationale in favour of integrating offline-capable upload buffering into future versions of the system, which would enable health center staff to initiate an upload transaction even when no connection is available, leaving the completion of the transaction up to the system when a connection is subsequently established.

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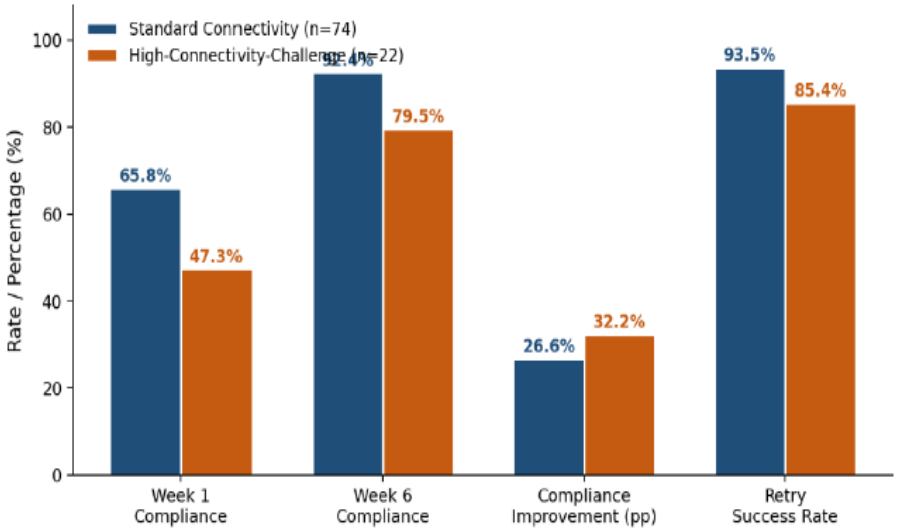


Figure 3. System Performance — Standard vs. High-Connectivity-Challenge Facilities

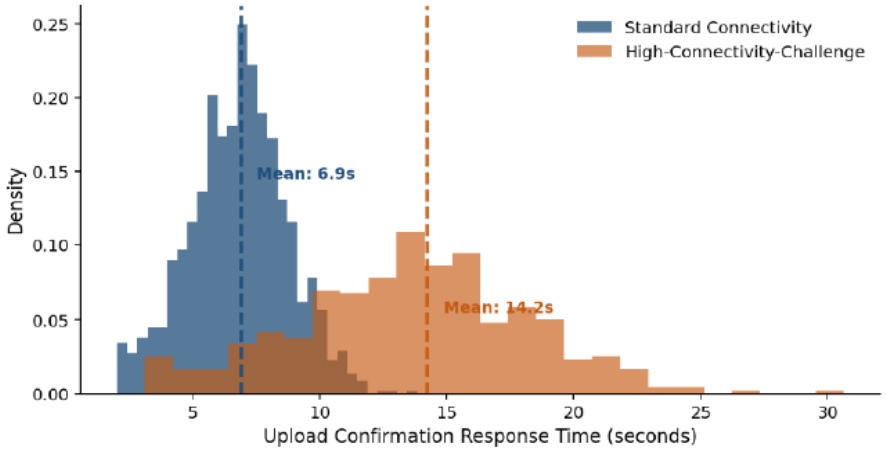


Figure 4. Distribution of Upload Response Times by Connectivity Category

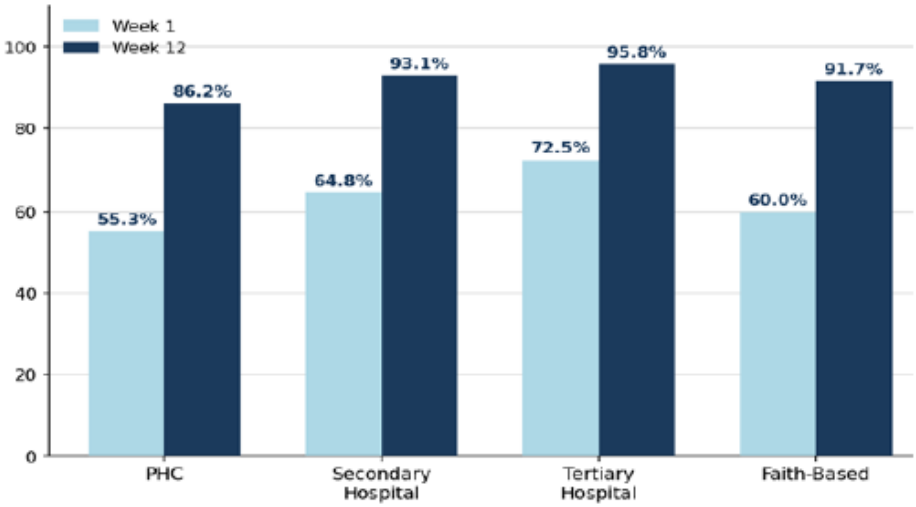


Figure 5. Compliance Rate by Facility Tier — Week 1 vs. Week 12

Documentation Compliance Trends

As highlighted earlier, the frequency of daily documentation was recorded over the 12-week pilot, and compliance increased throughout the duration of the trial. In the first week, compliance was 61.5%, compared with 89.6% by week 12. Therefore, compliance rose by 28.1 percentage points over the 12-week period. This pattern is consistent with mHealth implementation literature, which notes that automatic data collection systems often show compliance increases after an initial transition phase as staff adapt to a new workflow [19, 20].

Based on the learning curve of the Tanga region, we deduce that the barrier for documentation of incidents in the pre-automation phase was not the health workers' willingness, but rather the fact that the reporting was difficult. As mentioned earlier, [5] found that health information systems in several African health systems were inaccessible, which was a determinant to health workers' adoption of digital surveillance tools.

Comparative Advantage of the Approach

Our proposed system have many advantages when compared to current documentation tools. For example, users have to have access to the web via a browser in DHIS2, which is something that is generally not available due to low bandwidth in most areas, even in urban areas. This will not be the case for our proposed Telegram interface. In addition, HealthComX has shown that the use of instant messaging apps for health applications is also a viable option in limited resource settings, and given the near 100 % adoption of our interface in all 96 facilities that participated in compliance in our documentation interface also proves that our system has a very good potential for increasing the compliance of the necessary health sector documentation.

The automation project primarily relied on the workflow automation tool n8n. Adding new validation rules, notifications, and database queries could be implemented almost instantly without having to write code. No-code and mHealth implementation literature characterizes this type of platform as a rapid development approach that can support innovation in low-resource health systems [19, 20]. The PostgreSQL audit trail has made it possible to ensure that adherence to measurement, reporting, and documentation compliance can be verified and reported at any given time. National HMIS guidance identifies routine, auditable facility-level data as a core requirement for health information management, and the PostgreSQL audit trail satisfies this requirement [23].

Implications for AI-Powered Surveillance

The data on documentation compliance that is generated by the system also creates a source of primary data that can be used for other purposes in the future, in particular as part of AI-based surveillance activities. Recent AI surveillance literature emphasizes that high-quality, complete, and up-to-date data are necessary for these systems to realise their full surveillance capabilities [16, 17, 23]. The documentation collection and logging system described in this paper facilitates the automation of facility-record collection on a daily basis, thereby providing data infrastructure that can potentially support future AI-based disease surveillance activities.

Limitations

The following limitations were noted: The first limitation is related to the time period of the pilot, which was only 12 weeks, which is unlikely to account for all seasonal periods of documentation or long term behavioral changes. The system currently allows any ZIP to be submitted regardless of the contents of the files, which means that a non-compliant looking document (one that would fail when opened) as well as an empty or non-document file can be submitted, as the content validation

has not yet been implemented. Another limitation of the system as it is currently deployed is that many facilities, particularly those serving rural populations, have inconsistent internet availability. Finally, because our evaluation was the first of its kind (to our knowledge), we did not have a comparable control facility population to which to compare our evaluation group, because the current system for monitoring manual submissions was based on a large binder and form for documenting entries. This precludes our being able to know what percent of facilities in a given population would increase rates of submittal under the current system, thus it is harder to understand whether an increase in facilities with submittals following the implementation of our new technology is an actual effect of the technology, versus an effect of having a more user-friendly monitoring tool.

Conclusion

This paper delves into the design, implementation and assessment of an AI-enabled automation system for documenting health facilities' adherence to DRHS documentation standards in Nigeria. It tackles one of the key challenges faced by using AI in health surveillance, namely that facility data need to be properly captured, submitted, and aligned to a common standard before they can be processed and analyzed. As recent AI surveillance and infection-control studies emphasize, the potential of AI surveillance activities heavily depends on high-quality, complete, and up-to-date data [17, 21, 22].

The present study implemented digital health record tools across 96 health facilities in Nigeria. The evaluation showed that the system was reliable, user-friendly, and associated with improved documentation compliance from 61.5% to 89.6% over the 12-week pilot period. These findings are consistent with mHealth implementation literature and reviews of digital health initiatives in low-resource settings, which show that digital technologies designed around healthcare workers' routine practices and devices can address persistent health information management challenges [19, 20].

Content-level file validation, offline uploads, and integration with existing data stores such as DHIS2 should be validated in future work. Future development should also test AI analytics over structured data produced by the upload mechanism to support compliance-risk monitoring and predictive surveillance, consistent with recent literature on AI-enabled infection surveillance and health information systems [21-23].

Acknowledgement

The authors acknowledge the support of the health facility coordinators and program officers who participated in the pilot deployment of the system as well as the technical teams who provided the infrastructure required for the deployment and real time monitoring of the system during the validation exercise.

Funding Information

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author's Contributions

Conceptualization, resources, validation, formal analysis, investigation, data curation, writing original draft, writing review & editing and funding were conceived by the corresponding author. The corresponding author also implemented the initial data hosting, the overall system workflow architecture, and data analysis. All authors have read and agreed to the published version of the manuscript.

Ethical Approval

This study did not involve any clinical data or human subjects. All data available from the system consists of metadata related to uploaded files (facility ID, date/time, file name) and does not include any personal health information

(PHI). All healthcare workers used the system as part of their normal workflow activities and did so on a voluntary basis.

Data Availability

The aggregated data supporting the findings of this study are available from the corresponding author upon reasonable request. Facility-level operational audit logs are not publicly deposited because they contain program-specific metadata and facility identifiers.

Conflict of Interest

The authors declare that they have no conflict of interest.

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