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Long-acting Injectable Antipsychotics in Nigeria: A Systematic Review of Utilization, Treatment Outcomes, and Barriers to Access

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Abstract *Long-acting injectable (LAI) antipsychotics can be an optimal solution for sustained treatment of severe mental illnesses, but the evidence on their use and accessibility in Nigeria is limited. The study aimed to undertake a systematic review of available literature on the use of LAI, its outcomes, acceptability, and barriers in treating severe mental illnesses in Nigeria. The research was conducted using databases, including PubMed, Google Scholar, Bielefeld Academic Search Engine, and CORE. The inclusion criteria were studies that assessed the use of LAI in treatment, their outcomes, acceptability, and barriers in Nigeria. Three articles were considered in the research, of which one study met the inclusion criteria, involving 128 psychiatrists and psychiatry trainees. According to the findings, the attitudes towards LAI were generally positive, with an estimated number of patients with psychotic disorders who actually received LAI treatment being 41.7%. The most commonly administered long-acting antipsychotics are fluphenazine and flupenthixol decanoate. However, there was no evidence on the benefits of LAI at the individual level, including reducing the risk of relapse, readmission, and the likelihood of adherence to treatment, and recovery process. Moreover, the study identified barriers to LAI treatment, including the cost of medication, availability, accessibility due to transportation and clinic visits, injection administration process, and a burden on patients' families. In conclusion, the results demonstrated that LAI treatment is used and accepted among medical professionals in Nigeria. However, the evidence based on their effectiveness and cost-benefit is insufficient, which requires further high-quality multi-center studies.*

Keywords *Antipsychotics, Injectable, Long-Acting, Nigeria, Utilization.*

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Introduction

Severe mental illnesses such as schizophrenia and other psychotic disorders are a significant burden since they cause disability, shortened lifespan, morbidity, and mortality [1]. A long-term course of antipsychotic drugs is often necessary to control the symptoms of these diseases, but adherence to treatment is frequently challenging [2]. In addition, there are negative consequences of non-adherence, such as recurrence of symptoms, hospital admission, functional outcomes, and an increase in healthcare service use [3]. Low-income and middle-income nations like Nigeria, where healthcare services may be unavailable or unaffordable, have particular risks for inadequate adherence to mental illness treatments [4, 5].

Schizophrenia and other psychotic disorders are mainly treated with antipsychotic drugs. Treatment with antipsychotics usually aims to reduce positive symptoms and prevent the development and progression of the disease [6]. The most common way of administration is oral, since this method is convenient for both doctors and patients, and the dose of the drug is individually selected. However, patient adherence to treatment is often difficult to maintain, especially in the context of a lack of insight into the disease [7]. In addition, the side effects of drugs, reduced adherence, and frequent exacerbations are factors that negatively affect the patient's quality of life and increase morbidity and mortality. For these reasons, long-acting injectable antipsychotics are increasingly used in clinical practice. Such drugs can help maintain constant concentrations of the drug in the body, simplify dosing, support the doctor's attitude to the patient, especially in the case of missed doses, and reduce the risk of relapse and rehospitalization. However, the use of long-acting injectable antipsychotics may be limited by high costs, lack of availability, resistance, and contraindications.

Long-acting injectable (LAI) antipsychotics are depot designed to provide prolonged release of antipsychotic drugs for the management and maintenance treatment of severe mental disorders such as schizophrenia and other psychotic illnesses [8]. They are administered by intramuscular (IM) or subcutaneous (SC) injection on a regular schedule ranging from every 2 weeks to once every 6 months, depending on the specific medication. Unlike oral antipsychotics that need to be taken daily, LAI drugs maintain therapeutic levels of the medication in the body for an extended period, thus reducing the risk of missed doses [8]. The above advantages make LAIs ideal for patients with insight problems, cognitive impairment, treatment non-adherence, and frequent relapses.

The depot antipsychotic formulations can help manage treatment-resistant patients by improving treatment adherence and allowing more regular drug exposure, enabling early intervention in treatment failures. Moreover, they also minimize relapses and rehospitalization and prevent the development of irregular drug levels that might be associated with nonadherence [8]. However, LAIs are not superior to oral medications in all aspects; rather, their effectiveness depends on various factors, such as the choice of drug, treatment regimen, level of care, illness progression, incidence of adverse effects, and continuous care [9].

One of the most common features of LAIs is a relatively slow rate of absorption that often is slower than the rate of elimination from the body; this phenomenon is referred to as flip-flop kinetics [10]. Thus, the apparent half-life and the time needed to achieve steady-state concentrations are dictated primarily by the rate of absorption, not elimination [10]. Because of the slow absorption, therapeutic concentrations of the drug can be sustained for an extended period, allowing for dosing intervals as long as every two weeks to every six months. In addition, steady-state concentrations of LAIs are typically achieved within several half-lives,

but there is considerable variability between preparations [10].

The pharmacokinetic characteristics of individual LAIs differ significantly. Thus, the peak concentration of haloperidol decanoate after injection is achieved at 3–9 days and the apparent half-life of the drug is up to 3 weeks [11]. The peak plasma concentration of risperidone microspheres is not observed, while the initial dose of the drug is barely detectable, and significant amounts of it are detected in the blood three weeks after injection, which requires a start-up dose of oral medication [11]. The apparent half-life of paliperidone palmitate is relatively long, ranging from 25 to 49 days [12]. Moreover, it is eliminated mainly unchanged through the renal route, meaning that the function of the kidneys should be taken into account when selecting doses. On the other hand, aripiprazole formulations also possess a prolonged half-life, while for aripiprazole lauroxil, a very slow absorption and hence drug plasma concentration suggest itself.

Although LAI treatment offers many advantages over conventional antipsychotics, its optimal utilization in clinical practice is compromised by patient-, provider- and system-level barriers [13]. Patients may be reluctant to accept LAI treatment because of discomfort during injections, fear of needles, stigmatizing attitudes, invasiveness of the procedure, or a sense of loss of control [14]. Additionally, some patients report a more prolonged exposure to the medication that can increase the risk of side effects and require more frequent monitoring. From the provider's perspective, barriers to utilizing LAI drugs include high medication costs, cold storage requirements, IM administration technique, patient follow-up, and lack of treatment adherence. At a systemic level, the barriers include the availability of LAIs in the country or region and the extent to which coverage and reimbursement policies support the use of these medications. For example, in low- and middle-income countries like Nigeria, there is a high risk that patients will not be able to afford LAI drugs, and those who will not have consistent access to care. Overall, depot medications offer a useful approach to treating persons with psychotic illnesses, but their use requires addressing patient adherence and acceptance, affordability, availability, and the provision of continued care to patients.

The objective of this study is to examine the use of LAIs for treating severe mental illness, paying particular attention to their accessibility and impact on the delivery of mental health services in Nigeria. The use of antipsychotic drugs with long-acting injectables for the treatment of severe mental illnesses is an area of clinical practice that is both growing and vital. While LAIs have been extensively researched and reviewed in high-income countries, there is a lack of comparable studies in low-income and middle-income countries, such as Nigeria [15].

Our study seeks to answer several research questions related to the use and application of long-acting injectable antipsychotics in Nigeria. First of all, the research will be aimed at identifying the extent to which this type of intervention is prescribed and applied in different settings and among different patients. Moreover, the study will be focused on analyzing the outcomes of such treatment, clarifying its impact on the symptoms, likelihood of relapse and rehospitalization, and the patients' overall functioning and quality of life. It will also be important to highlight adherence to the treatment, possible recurrence or relapse, and the occurrence of any side effects or adverse events.

Furthermore, the study will provide a basis for understanding the factors affecting the use of long-acting injectables for the treatment of severe mental illnesses. It will be important to highlight the patient-, provider-, and system-level factors associated with the use of long-acting injectables and identify barriers to their use and the reasons for such limitations. The analysis will be based on the evaluation of

cost-effectiveness, availability, and cultural acceptability of these interventions as well as clinicians' attitudes toward them and patients' access to continued care. Lastly, the study will identify the most pressing issues affecting mental health care delivery in Nigeria and evaluate how these issues affect the provision of treatment and the patient's access to it. The study has implications for clinical practice by examining existing practices in the treatment of severe mental illnesses with LAIs. It highlights areas of deficiency in terms of accessibility and use in order to inform mental health policy, treatment recommendations, pharmaceutical availability, and future research. A systematic evaluation of the literature regarding the use of LAIs for the treatment of severe mental illnesses in Nigeria will help to identify critical evidence gaps regarding their use, treatment outcomes, and barriers to their adoption.

Methods

We performed a systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines 2020 [16].

Studies were considered for inclusion if they: (a) were carried out in Nigeria; (b) Studies with participants diagnosed with schizophrenia, schizoaffective disorder, bipolar illness or other serious mental illnesses who were administered antipsychotic medication in Nigeria; (c) Studies evaluating the use of long-acting injectable antipsychotics such as first- and second-generation antipsychotics including haloperidol decanoate, fluphenazine decanoate, risperidone LAI, paliperidone, aripiprazole, other LAIs approved for use in the treatment of mental illness; (d) Studies reporting the use, indication(s), acceptance (patient or clinician), cost or affordability issues, availability and accessibility, and patient-related or socioeconomic barriers to Long-acting injectable treatment; (e) Randomized controlled trials, cohort studies, cross-sectional studies, case-control studies, observational studies, qualitative studies and relevant case series/reports, which contribute data to the topic of LAI treatment in Nigeria.

We conducted a systematic search of the literature using the search terms "Long-Acting Injectable antipsychotic in Nigeria", "Long-Acting Injectable antipsychotic utilization in Nigeria", and "Acceptability of Long-Acting Injectable antipsychotic in Nigeria", in PubMed, Google scholar, Bielefeld Academic Search Engine, and CORE. No language or publication date restrictions were applied.

Results

We located three articles via the database search. After screening the titles and abstracts, the inclusion/exclusion criteria was applied to check the relevance of the articles. As a result, only one study was included in the final review, whereas the others were excluded due to the lack of the relevance to the research question.

Table 1. Articles on LAIs Utilization in Nigeria

Authors	Psychiatrists' Attitude	Patients' Acceptance (%)	Participants Enrolled	Methodology	Findings
James et al 2012 [7]	Positive	41.7	128	Cross sectional study	Different desirability due to perceived potency

As seen in the Table 1, above, the researchers reported that respondents estimated that, on average, 67.9% of their patients had a psychotic disorder (SD = 15.5%; range, 10-90%), of whom approximately 41.7% were prescribed a long-acting injectable (LAI) antipsychotic (SD = 21.8%; range, 5-100%) [14]. Fluphenazine decanoate was the most frequently prescribed LAI by 120 respondents (93.8%) during the past year, whereas

flupenthixol decanoate was the second most frequently prescribed LAI by 108 respondents (84.4%).

For the maintenance treatment of schizophrenia, second-generation antipsychotics (SGAs) in oral formulation were the preferred first-choice therapy by 60.2% of participants, followed by first-generation antipsychotics (FGAs) in oral formulation (21.9%), FGA-LAIs (7.8%), and risperidone LAI (5.5%). Moreover, 4.6% of respondents had no preferred first-choice treatment. Oral FGAs were selected as the preferred second-choice treatment by 41.4% of respondents, followed by FGA-LAIs (36.7%), oral SGAs (17.9%), and SGA-LAIs (2.3%). In addition, two respondents had no preferred second-choice treatment.

Discussion

In general, the systematic review revealed a substantial lack of evidence supporting LAI utilization in Nigeria. Indeed, only three articles were identified via database screening, and only one study was eligible for inclusion. The study by James et al. was conducted among 128 psychiatrists and psychiatry trainees, who provided insights into the perspectives and attitudes of these professionals towards LAI treatment. The findings of James et al. as seen in the table 1 above, cannot be used to confirm the effectiveness of LAIs in terms of reducing relapse rates, hospitalization, functional recovery, or adherence since the study aimed to explore healthcare providers' experiences and did not attempt to evaluate the clinical outcomes of LAI utilization in Nigeria. Thus, the reviewed evidence is insufficient to draw any final conclusions on the effectiveness and barriers to LAI use in the country. Moreover, it is evident that there are very few studies on LAI utilization in Nigeria.

The identified study provides some evidence on the use of LAIs in Nigerian hospitals. According to the findings by James et al., 41.7% of psychiatrists' psychotic patients were prescribed LAI, but it should be noted that this figure was probably overestimated since it was based on clinicians' declarations rather than patient records [14]. In South Africa, LAIs are prescribed mainly for noncompliance to medications [17]. The study by James et al., revealed that the most commonly administered long-acting antipsychotics were fluphenazine decanoate and flupenthixol decanoate, which are first-generation antipsychotics [14]. This finding might suggest that there is no significant preference for newer generations of LAIs in Nigeria. Indeed, it is reasonable to assume that the observed prescribing pattern is guided by cost-effectiveness since first-generation antipsychotics are significantly cheaper than their second- and third-generation alternatives. However, there are recently approved LAIs by Food and Drug Administration (FDA) in the US [18]. These include olanzapine, paliperidone, and risperidone which are very potent according to research [19]. They are relatively expensive, but they have lower risk of side effects including abnormal movement disorder [20]. Thus, there is a need for advocacy for the availability, accessibility, and insurance coverage of newer LAIs in Nigeria to ensure the provision of high-quality psychiatric care and treatment for patients with psychotic disorders. Medication price, transportation, clinic visits' frequency and cost, injection administration, and the family's capacity to cope with the treatment burden are all potential disruptors of treatment continuity [21]. Reducing these barriers could lessen the burden on patients and families and improve continuity of treatment and long-term outcomes [22, 23].

The identified study also revealed that Nigerian psychiatrists have generally positive attitudes towards LAIs [14]. The participants had a positive attitude towards the use of injectable treatment, and those who prescribed LAIs to more than 40% of their patients were more likely to report positive patient-centered attitudes. Since clinician attitudes are important

predictors of the likelihood of injectable treatment being discussed and incorporated into shared treatment planning, this finding is critical. In Kwazulu-Natal, South Africa, (94.3%) reported a positive drug attitude towards their antipsychotic medication, including LAIs [24]. However, the reported level of knowledge on LAIs and their adverse effect was only fair, meaning that positive clinician attitudes towards long-acting antipsychotics do not necessarily coincide with a comprehensive understanding by the patient [25]. Patients' understanding of medication profile is a key factor influencing their choices [26]. Thus, it is imperative that continuing medical education is essential for ensuring that clinicians can provide evidence-based care and obtain informed consents from their patients.

A major limitation of the evidence presented is the lack of relevant Nigerian studies assessing patient-level outcome. The only included study evaluated the knowledge, attitude, and self-reported practice of Nigerian psychiatrists rather than objective measures such as incidence of relapse or rehospitalization, persistence with treatment, quality of life, functional recovery, or adverse events. Therefore, it remains unknown whether the relatively high prevalence of LAI use among Nigerian psychiatrists identified in this review is associated with better patient outcomes. Although international evidence suggests that LAIs may be beneficial for selected patients, including those who fail to adhere to oral antipsychotics, the magnitude of effect can vary depending on the study population, design, active control, and treatment setting [27, 28]. Therefore, further research in Nigerian settings is needed before firm conclusions regarding the comparative effectiveness and appropriateness of LAIs for improving health outcomes can be drawn.

Conclusion

In general, the obtained results demonstrate that long-acting injectable antipsychotics (LAIs) were accepted and used within the framework of Nigerian psychiatric practice; psychiatrists have a positive attitude towards their use. However, the evidence is insufficient to determine their effectiveness, comparative clinical outcome, long-term adherence to treatment, and cost-effectiveness in Nigeria. The data obtained underline the need to improve the knowledge of clinicians and the importance of developing patient-oriented approaches and reducing financial and availability barriers. Most importantly, the identified evidence gap related to the absence of contemporary studies conducted in Nigeria was revealed, which can be addressed through a multicenter, patient-centered, and prospective study aiming to ensure rational use of LAI antipsychotics in the country.

Conflict of Interest

The authors affirm that they do not have any financial affiliations presently or within the preceding three years with any organizations that could potentially influence the submitted work. They further assert that no other associations or engagements might give rise to perceived influences on the submitted work. The authors confirm the absence of any conflicts of interest. All authors provide their consent for the publication of this manuscript.

Ethical Approval

This is a systematic review; ethical approval is not needed.

Authors' Contributions

All authors contributed to the project's conception and design, as well as the development of the project. All authors participated in the literature review, data analysis, and manuscript preparation. All authors approve the final version of the manuscript for submission.

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Data Availability

The data set related to this study was from the only paper that met the inclusion criteria.

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Determinants of Under-five Mortality in Cameroon (1991–2018): A Survey-weighted Comparison of Cox and Discrete-time Hazard Models

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Abstract *Identifying independent determinants of under-five mortality (U5M) in Cameroon requires survival methods that properly account for the complex sampling design of DHS data. This study compares survey-weighted Cox proportional hazards regression and a discrete-time hazard model, applied to the same pooled dataset of five DHS waves (1991–2018): 35,257 live births, 2,968 under-five deaths, and 1,821 primary sampling units. Cox models were built sequentially across four covariate blocks, with model discrimination tracked at each step. As a robustness check, a discrete-time logit model with a natural cubic spline for time was fitted to 922,995 person-months. The proportional hazards assumption held globally and for every covariate. In the final Cox model (concordance=0.655), female sex (HR = 0.915, p = 0.033), maternal education (HR = 0.867 per level, p < 0.001), maternal age (HR = 0.956 per year, p < 0.001), and residence in the West region (HR = 0.675, p = 0.001) were significantly protective, while parity was the strongest risk factor (HR = 1.167 per child, p < 0.001), two other regions carried significant excess hazard, and the 2004 survey wave showed an independently elevated hazard (HR = 1.341, p < 0.001) unattenuated by covariate adjustment. The discrete-time model reproduced every Cox finding within 1%, with full concordance across all eighteen coefficients, and five sensitivity analyses left every finding unchanged (concordance 94–100%). These results demonstrate that Cox and discrete-time hazard models yield equivalent, highly robust conclusions for Cameroonian U5M determinants, and that parity reduction, maternal education, and later maternal age represent the most consistent protective targets for child survival policy, alongside the persistently protective profile of the West region.*

Keywords *Cameroon, Cox Proportional Hazards, Determinants, Discrete-Time Hazard, Maternal Education, Parity, Sensitivity Analysis, Survey-Weighted, Survival Analysis, Under-Five Mortality DHS.*

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Introduction

Background

Identifying modifiable determinants of under-five mortality (U5M) is a prerequisite for designing effective, targeted child health interventions. In low- and middle-income countries, Demographic and Health Surveys (DHS) remain the richest available source of longitudinal data on child survival, yet their complex sampling design, involving stratification, clustering, and differential probability weighting, demands specialized analytical methods that are frequently applied incompletely or incorrectly in the published literature [1, 2]. Studies that ignore clustering routinely understate standard errors and report spuriously significant associations, a methodological pitfall this analysis was designed to avoid at every stage.

The Cox proportional hazards model has long served as the reference method for survival analysis; it assumes that each covariate's hazard ratio remains constant over follow-up time, an assumption commonly termed proportional hazard (PH) [3]. When this assumption is satisfied, the model yields valid and directly interpretable covariate effect estimates without requiring a parametric form for the baseline hazard. The Cox model, however, does not explicitly model the probability of the event within each discrete time unit, a limitation addressed by the discrete-time hazard model, which reframes survival as a sequence of repeated binary outcomes, died or survived, at each time interval and offers greater flexibility in shaping the baseline hazard [4].

Research Gap

Both methods have been applied independently to DHS child survival data across African settings [5, 6], yet a systematic, head-to-head comparison under identical data conditions, same population, same covariates, same survey-design correction, has rarely been undertaken for Cameroon [7]. Such a comparison carries practical value: it tests whether substantive findings are robust across methodological choices, and it gives future researchers concrete evidence on the equivalence, or divergence, of these two tools when applied to DHS-type data. Equally, few studies subject their principal findings to a structured battery of sensitivity analyses; this study addresses that gap by pairing the primary Cox and discrete-time comparison with five independent robustness checks spanning outcome definition, covariate specification, weighting strategy, pooling strategy, and estimation software.

Objectives

This study pursues four objectives:

1. To estimate the independent determinants of U5M in Cameroon (1991–2018) using survey-weighted Cox proportional hazards models built through sequential covariate blocks, tracking model discrimination at each stage.
2. To replicate this analysis with a discrete-time logit model, using person-month expansion of the dataset and a natural cubic spline to flexibly model the baseline hazard over time.
3. To formally compare the two models on directional consistency, magnitude of estimated effects, and statistical significance across all included covariates.
4. To test the robustness of the principal findings through five independent sensitivity analyses covering outcome window definition, alternative covariate coding, weighting strategy, pooling strategy, and estimation software.

Methods

Study Population and Data

Table 1 summarizes the five DHS waves (1991, 1998, 2004, 2011, 2018) pooled for this analysis. The 2022 Malaria Indicator Survey was excluded because it did not collect the age-at-death variable (b7), which is essential for

constructing the survival-time outcome. The final analytical sample comprised 35,257 live births and 2,968 deaths, pooled across five distinct survey designs using composite primary-sampling-unit identifiers (wave × cluster) and composite stratum identifiers (wave × stratum) to prevent the designs from being artificially merged during variance estimation.

Table 1. Analytical Sample by Survey Wave

Wave	N Births	N Deaths	Crude Death Rate	Inclusion Status
1991	3,350	284	8.5%	Included
1998	2,317	194	8.4%	Included
2004	8,125	844	10.4%	Included
2011	11,732	998	8.5%	Included
2018	9,733	648	6.7%	Included
2022 (MIS)	4,506	164	3.6%	Excluded (b7 not collected)
POOLED TOTAL	35,257	2,968	8.4%	5 of 6 waves, 1,821 composite PSUs

Note: *Crude death rate = unweighted deaths / births × 100, shown for descriptive orientation only; all inferential estimates in this article use survey-weighted methods described below.*

Outcome and Survival Variable Construction

Survival time was defined as age at death in completed months (b7) for children who died before their fifth birthday (b5 = 0, b7 ≤ 59), or as age at interview in months (v008−b3), right-censored at 59 months, for children still alive at interview. The event indicator equalled 1 for deaths occurring before 60 months and 0 for censored observations. Formally:

$time_i = b7_i$ if $b5_i = 0$ and $b7_i \leq 59$ (death before 60 months); $time_i = v008_i - b3_i$, truncated at 59 months, if $b5_i = 1$ (child alive at interview).

$event_i = 1$ if $b5_i = 0$ and $b7_i \leq 59$; $event_i = 0$ otherwise.

Covariates: Sequential Block Structure

Covariates were introduced across four sequential blocks to assess the stability of estimated effects and the incremental contribution of each domain as successive layers of adjustment were added, summarized in Table 2.

Table 2. Covariate Blocks Used in the Sequential Cox Models

Block	Variables Added	Rationale
Block 1	Sex (b4); survey-wave fixed effects	Child characteristics; controls for period effects
Block 2	+ Maternal education (v106); maternal age (v012)	Maternal human capital and biological factors
Block 3	+ Residence (v025); region (v024)	Household context and geographic access to care
Block 4 (final)	+ Parity (v201)	Reproductive behavior and sibling competition

Cox Model Specification

The survey-weighted Cox proportional hazards model was estimated via svycoxph() (survey package, R 4.6.0) [17, 18], with the complex design declared using wave×PSU as the cluster identifier, wave×stratum as the stratum identifier, and v005/1,000,000 as sampling probability weights. The model takes the semi-parametric form:

$$h(t|X) = h_0(t) \times \exp(\beta_1 \cdot \text{sex} + \beta_2 \cdot \text{wave} + \beta_3 \cdot \text{maternal_educ} + \beta_4 \cdot \text{maternal_age} + \beta_5 \cdot \text{residence} + \beta_6 \cdot \text{region} + \beta_7 \cdot \text{parity})$$

where $h_0(t)$ is the non-parametric baseline hazard. The β coefficients were estimated by maximizing the Cox partial likelihood, weighted by DHS sampling probabilities, with the Huber-White robust variance estimator correcting standard errors for within-cluster correlation. The proportional hazards assumption was tested for each covariate individually and globally using Schoenfeld residuals via cox.zph(), a non-significant test ($p>0.05$) supports the assumption that a given covariate's effect does not vary systematically over follow-up time.

Discrete-Time Hazard Model Specification

Each birth record was expanded into one row per month at risk, from month 1 to the observed survival time, generating a person-month dataset of 922,995 rows. A logistic regression model was then fitted via svyglm() with a quasibinomial family and logit link, incorporating a natural cubic spline of month (ns (month, df = 4)) to flexibly capture the shape of the baseline hazard across the 60-month observation window:

$$\text{logit}\, P(\text{death}_{\text{month}}|X) = \text{ns}(\text{month}, \text{df} = 4) + \beta_1 \cdot \text{sex} + \beta_2 \cdot \text{wave} + \beta_3 \cdot \text{maternal_educ} + \beta_4 \cdot \text{maternal_age} + \beta_5 \cdot \text{residence} + \beta_6 \cdot \text{region} + \beta_7 \cdot \text{parity}$$

All Block-4 covariates from the Cox specification were included identically in this model, allowing a like-for-like comparison of estimated effects.

Formal Model Comparison

Cox hazard ratios and discrete-time odds ratios were extracted using tidy (exponentiate = TRUE, conf.int = TRUE) from the broom package. Concordance between the two approaches was assessed on three criteria: direction of effect (sign consistency), statistical significance at the $p < 0.05$ threshold, and relative percentage discrepancy between point estimates.

Sensitivity Analyses

Five sensitivity analyses were planned prior to reviewing the main results, to test whether the principal findings depended on specific analytical choices:

1. Neonatal-window definition: comparing the standard 28-day neonatal cutoff against a 30-day alternative to test sensitivity of the neonatal mortality estimate to boundary placement.
2. WASH-access coding, strict version: testing a stringent Joint Monitoring Programme (JMP) definition of improved water and sanitation as an additional covariate.
3. WASH-access coding, broad version: testing a phase-aware, more permissive definition of improved WASH access as an alternative covariate specification.
4. Weighting strategy: comparing raw DHS sampling weights against wave-normalized weights to test sensitivity to weight construction.
5. Estimation approach: comparing pooled multi-wave modelling against wave-specific models estimated separately, and comparing the survey-weighted svycoxph() engine against the native, non-weighted coxph() engine.

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Results

Descriptive Overview of the Analytical Sample

The pooled sample spans 31 years of demographic change, with the number of births per wave ranging from 2,317 (1998) to 11,732 (2011), reflecting differences in sample design and fieldwork budget across survey rounds rather than substantive demographic shifts. Figure 1 and Figure 2 summarize the raw death counts and crude death rates underlying the survival analysis.

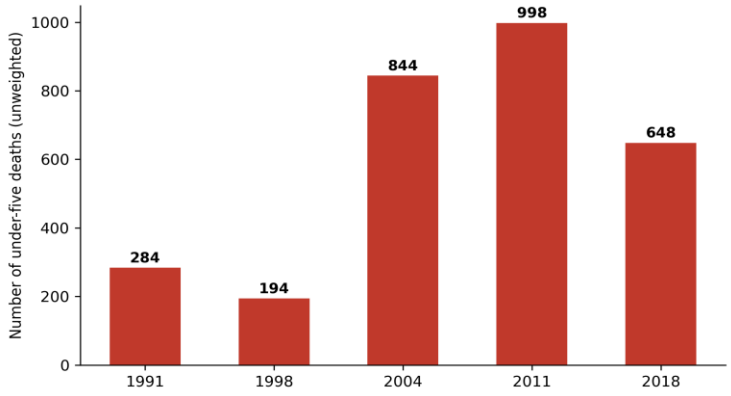


Figure 1. Observed Deaths Contributing to the Pooled Survival Analysis, by Wave

Unweighted counts of under-five deaths recorded in each survey wave, prior to any survey-weight adjustment. Source: DHS Cameroon 1991–2018.

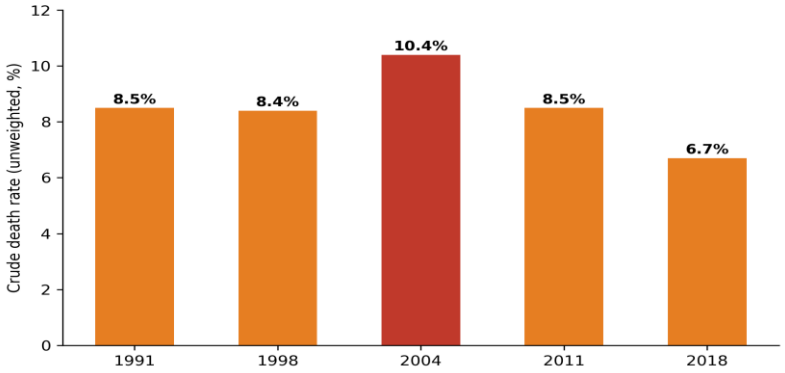


Figure 2. Crude Death Rate Among Included Births, by Survey Wave

Unweighted deaths / births × 100 per wave. The 2004 wave, highlighted in dark red, recorded the highest crude rate across all five waves entering the survival analysis.

The 2004 wave stands out immediately in this purely descriptive view, with a crude death rate of 10.4%, roughly two percentage points above every other wave. Whether this elevated crude rate persists after full covariate adjustment, and after accounting for the complex survey design, is addressed directly by the Cox and discrete-time models presented below.

Kaplan-Meier Survival Analysis by Residence

Before fitting the multivariable Cox and discrete-time models, weighted Kaplan-Meier survival curves were estimated by residence (urban versus rural) using svykm(), providing a descriptive, covariate-free picture of the survival gap that the subsequent multivariable models seek to explain (Figure 3).

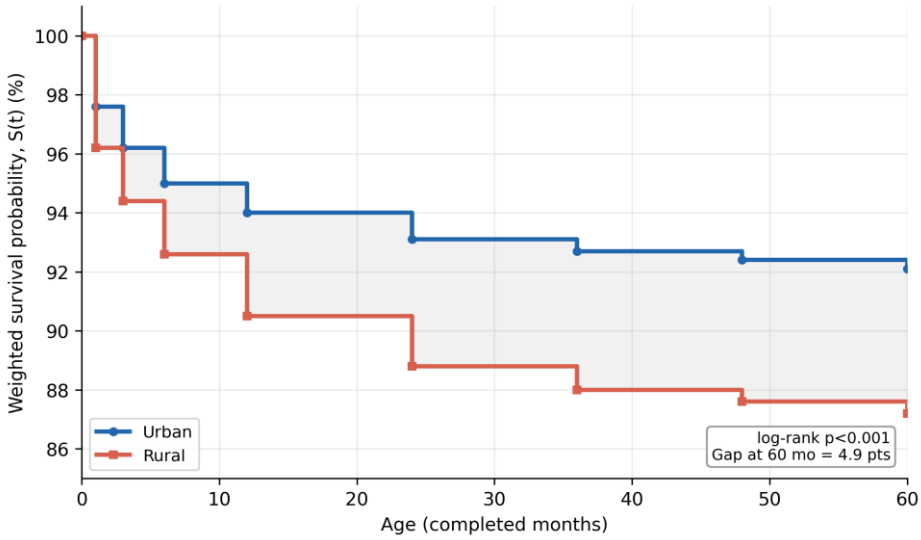


Figure 3. Weighted Kaplan–Meier Survival Curves — Urban vs. Rural Residence

Weighted probability of survival to a given age, by residence. Weighted log-rank test: p<0.001. Source: survey::svykm(), DHS Cameroon 1991–2018.

By 60 months, weighted survival stood at 92.1% in urban areas versus 87.2% in rural areas, a gap of 4.9 percentage points that emerged early in life and remained essentially stable across the full follow-up window, indicating a risk differential present from birth rather than one that accumulates disproportionately at a specific age. This unadjusted gap sets the benchmark against which the multivariable residence coefficient, reported below, can be interpreted.

Proportional Hazards Assumption

The global Schoenfeld residual test showed no evidence of departure from proportional hazards ($\chi^2 = 4.33 \times 10^{-3}$, df = 20, p = 1.00). Every individual covariate test likewise returned a non-significant result, detailed in Table 3.

Table 3. Schoenfeld Residual Test of the Proportional Hazards Assumption, by Covariate

Covariate	Schoenfeld χ^2	df	p-value	Verdict
Sex	3.36×10^{-4}	1	0.99	PH holds
Survey wave	1.31×10^{-3}	4	1.00	PH holds
Maternal education	1.49×10^{-3}	1	0.97	PH holds
Maternal age	1.07×10^{-5}	1	1.00	PH holds
Residence	9.50×10^{-4}	1	0.98	PH holds
Region (11 categories)	2.05×10^{-3}	11	1.00	PH holds
Parity	7.28×10^{-6}	1	1.00	PH holds
GLOBAL TEST	4.33×10^{-3}	20	1.00	All covariates satisfy PH

Note: *A non-significant Schoenfeld test (p>0.05) indicates no evidence that a covariate's hazard ratio changes over follow-up time, supporting the validity of the proportional hazards specification used throughout this study.*

Sequential Block Building and Model Discrimination

Model discrimination, measured by Harrell's concordance statistic, improved steadily as each covariate block was added, summarized in Table 4 and Figure 4.

Harrell's concordance statistic (C) at each stage of covariate addition. A value of 0.5 indicates no discrimination; higher values

indicate better ability to rank-order survival times correctly. Source: svycoxph (), R 4.6.0.

The largest single gain in discrimination came from adding maternal characteristics (Block 2, +0.054), followed by household and geographic context (Block 3, +0.033) and parity (Block 4, +0.026). Each successive block therefore contributed meaningfully and independently to the model's ability to distinguish higher-risk from lower-risk births, justifying the sequential block-building strategy adopted for this analysis.

Table 4. Sequential Cox Model Summary Across Covariate Blocks

Block	Variables	N	Concordance (C)
Block 1	Sex, survey-wave fixed effects	35,257	0.542
Block 2	+ Maternal education, maternal age	35,257	0.596
Block 3	+ Residence, region	35,257	0.629
Block 4 (final)	+ Parity	35,257	0.655

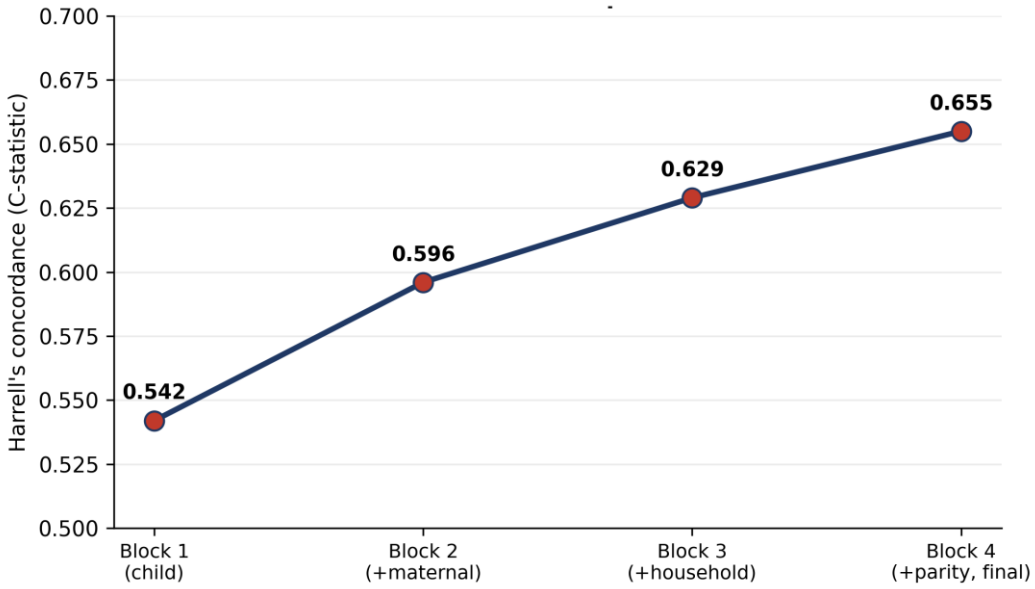


Figure 4. Model Discrimination Across Sequential Covariate Blocks

Final Cox Model: Adjusted Hazard Ratios

Table 5. Adjusted Hazard Ratios — Final Cox Model, Block 4 (n = 35,257 births; 2,968 events)

Variable (reference)	HR	95% CI	p-value	Significance
Female sex (ref. male)	0.915	[0.843–0.993]	0.033	* protective
Wave 1998 (ref. 1991)	1.077	[0.881–1.317]	0.470	ns
Wave 2004 (ref. 1991)	1.341	[1.136–1.583]	<0.001	*** elevated hazard
Wave 2011 (ref. 1991)	1.174	[0.996–1.384]	0.056	ns (borderline)
Wave 2018 (ref. 1991)	0.841	[0.707–1.002]	0.052	ns (borderline)
Maternal education (per level)	0.867	[0.809–0.929]	<0.001	*** strong protective
Maternal age (per year)	0.956	[0.945–0.967]	<0.001	*** strong protective
Rural residence (ref. urban)	1.091	[0.986–1.207]	0.091	ns after adjustment
Region 8 — West (ref. Region 1)	0.675	[0.531–0.858]	0.001	** most protective region
Region 10 — South-West (ref. Region 1)	1.259	[1.011–1.567]	0.040	* excess risk

Region 11 — Yaoundé/Centre-Urb. (ref. Region 1)	1.251	[1.004–1.560]	0.047	* excess risk
Parity (per additional child)	1.167	[1.132–1.202]	<0.001	*** key risk factor

Note: *HR = hazard ratio; CI = confidence interval. Model concordance = 0.655. Global proportional hazards test:* $\chi^2=4.33\times10^{-3}$*, df=20, p=1.00.*

Table 5 is the central result of this article: it lists every covariate retained in the final, fully adjusted model, alongside the size, direction, and statistical precision of its association with under-five mortality. Seven of the twelve rows reach conventional significance ($p < 0.05$). Reading down the hazard-ratio column, parity carries the largest deleterious effect of any single-unit change (HR = 1.167 per child), while maternal education carries the largest single-unit protective effect (HR = 0.867 per level). The wave dummies show that only 2004 reaches significance in isolation, foreshadowing the period-effect analysis presented in Figure 8.

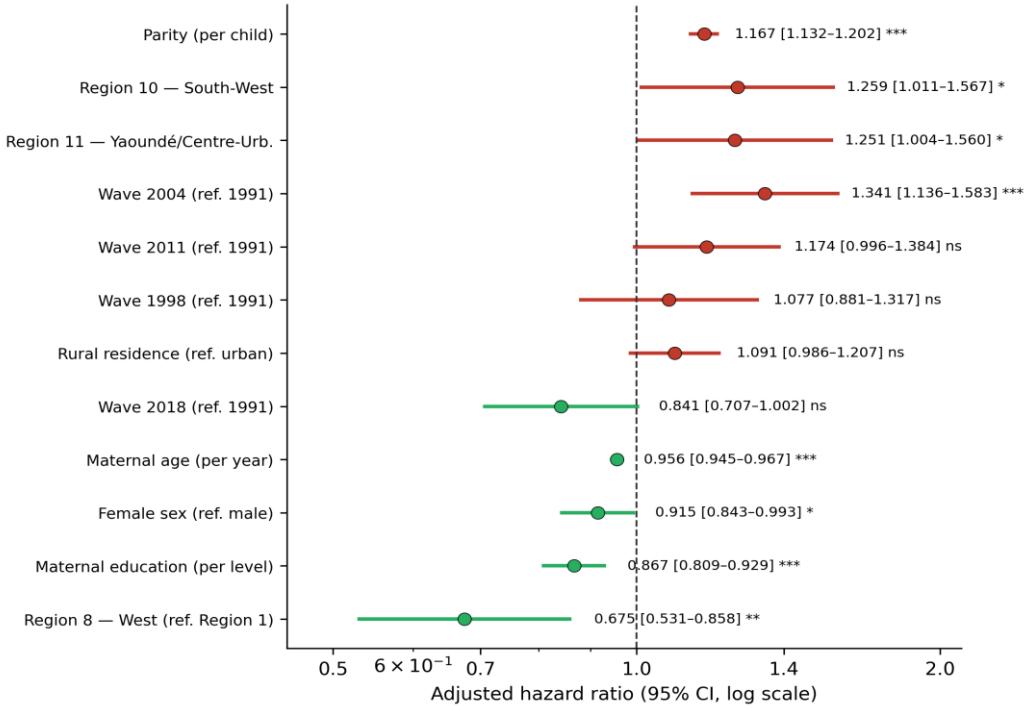


Figure 5. Full Forest Plot — Final Cox Model, All Covariates

Points show adjusted hazard ratios (log scale); horizontal bars show 95% confidence intervals. The dashed vertical line marks the null value (HR = 1.0). Green: protective; red: risk-increasing; grey: not statistically significant. Source: svycoxph(), R 4.6.0.

The forest plot translates Table 5 into a single visual scan: the further a point sits from the dashed null line, and the narrower its confidence interval, the more confidently that variable can be treated as a genuine determinant rather than a chance finding. Two clusters are visually apparent. A protective cluster (green, left of the null line) groups maternal education, maternal age, female sex, and Region 8, none of whose intervals cross 1.0. A risk-increasing cluster (red, right of the null line) groups parity, the two significant regions, and the 2004 wave. The grey markers, rural residence and the three non-2004 wave dummies, illustrate variables whose point estimates suggest an effect, but whose confidence intervals are too wide, given the available sample size within each subgroup, to rule out chance.

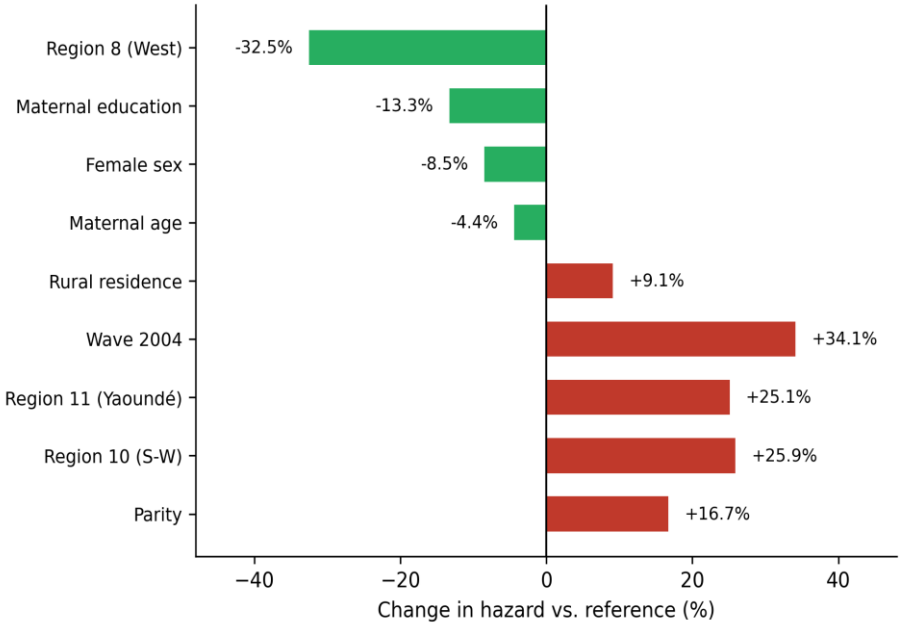


Figure 6. Percentage Change in Under-Five Mortality Hazard by Determinant

Percentage change in hazard relative to the reference category, ordered from largest risk-increasing to largest protective effect. Derived from Table 5.

Where Figure 5 emphasizes statistical confidence, Figure 6 emphasizes practical magnitude by re-expressing each hazard ratio as a percentage change, a framing better suited to communicating results to a policy audience unfamiliar with hazard ratios. On this scale, each additional birth raises the hazard by 16.7%, nearly identical in magnitude to the 25.9% and 25.1% excess hazard carried by Regions 10 and 11, while residing in Region 8 lowers the hazard by 32.5%, the single largest protective margin of any covariate in the model.

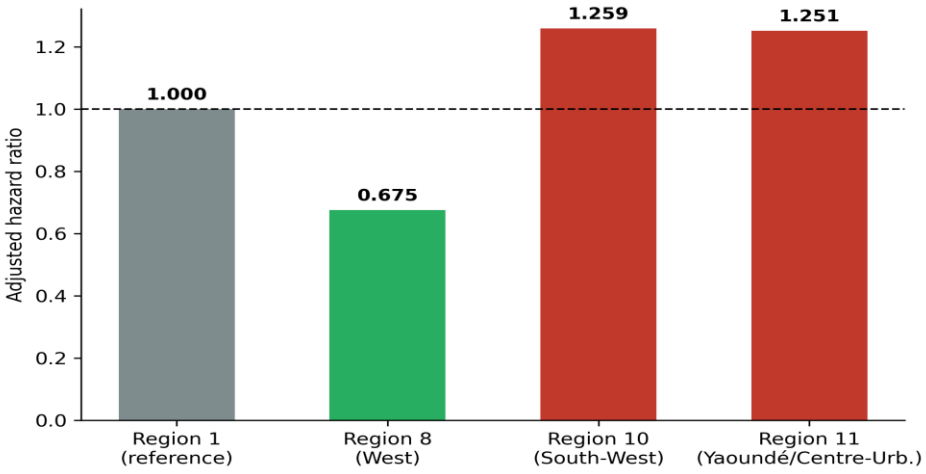


Figure 7. Regional Hazard Ratios Reaching Statistical Significance

Adjusted hazard ratios for the three regions reaching statistical significance in the final Cox model, relative to Region 1. Region 8 (West) is protective; Regions 10 and 11 carry excess hazard.

Figure 7 isolates the geographic dimension of Table 5 for closer inspection. The visual asymmetry is deliberate: only three of Cameroon's regions clear the significance threshold once maternal, household, and

reproductive characteristics are held constant, meaning that most of the country's regional variation in crude mortality, documented descriptively in the companion trends analysis (Article 1 of this series), is explained by compositional differences in who lives where rather than by residual, region-specific risk. The three regions that do remain significant after this adjustment are therefore the strongest candidates for genuinely place-based, rather than purely population-based, intervention.

Taken together, Table 5 and Figures 5–7 establish that parity is the most stable and quantitatively important risk factor in this analysis (HR = 1.167 per child, $p < 0.001$), a pattern that held across every wave-specific model estimated as part of the sensitivity analyses reported below. Maternal education and maternal age were both strongly protective, while three regions reached statistical significance after full adjustment: Region 8 (West) as protective, and Regions 10 (South-West) and 11 (Yaoundé/Centre-Urban) as carrying excess hazard relative to the reference region.

Period Effect: The 2004 Wave

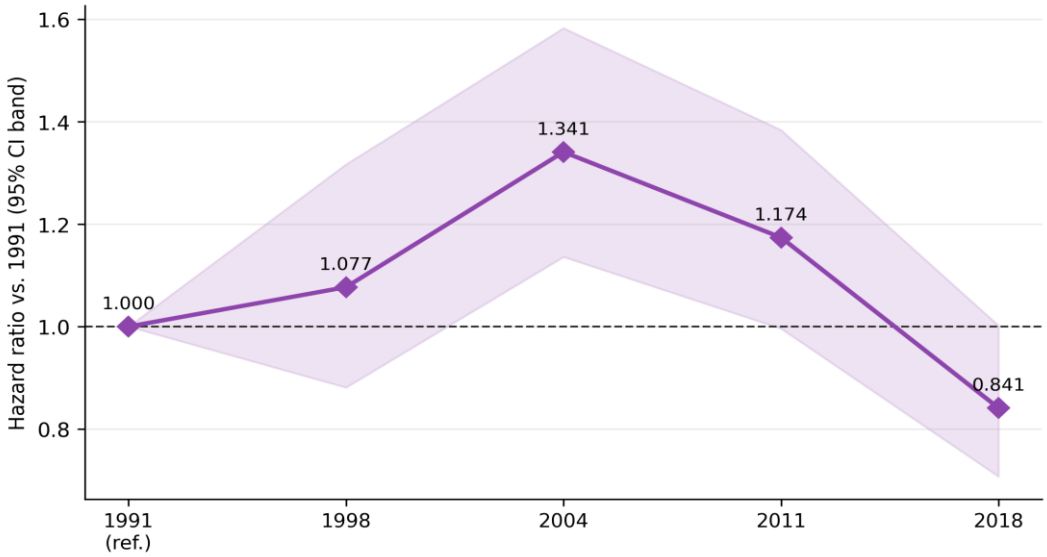


Figure 8. Period (Survey-Wave) Effect on Under-Five Mortality Hazard, 1991–2018

Adjusted hazard ratio for each survey wave relative to 1991 (reference), with 95% confidence band. All estimates come from the final Block-4 Cox model, meaning the 2004 elevation persists after adjustment for sex, maternal characteristics, residence, region, and parity.

The 2004 wave carried an independently elevated hazard of 1.341 (95% CI: 1.136–1.583, $p < 0.001$) relative to 1991, the only wave dummy reaching conventional significance in either direction. Because this effect persists after adjusting for individual, maternal, household, and geographic characteristics, it reflects something specific to the 2004 survey period itself rather than a compositional artifact of who was sampled that year.

Discrete-Time Hazard Model

The discrete-time model converged after ten Fisher scoring iterations on the expanded 922,995-row person-month dataset, with a dispersion parameter of 1.026 consistent with the absence of meaningful overdispersion.

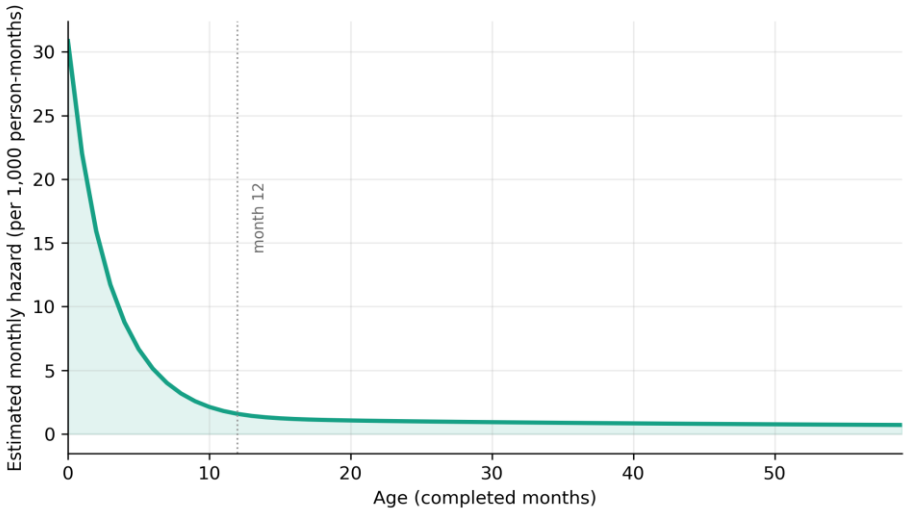


Figure 9. Discrete-Time Baseline Hazard — Natural Cubic Spline, ns (month, df=4)

Estimated monthly hazard of death (per 1,000 person-months at risk) as a function of age, from the discrete-time logit model's spline term. The curve traces a sharply declining hazard from birth through month 12, followed by a low, stable plateau through month 59.

The spline traces something the Cox model's semi-parametric baseline hazard cannot directly show: the precise shape of risk over age. The curve is steepest in the first weeks of life, falls by more than half by month 12, and then flattens into a long, low plateau through month 59. Because this shape is estimated with only four degrees of freedom, it is a smoothed summary rather than a month-by-month estimate, but the qualitative message, that risk is concentrated overwhelmingly in the earliest months, matches the neonatal-mortality concentration documented independently at the national level in the companion trends analysis (Article 1 of this series).

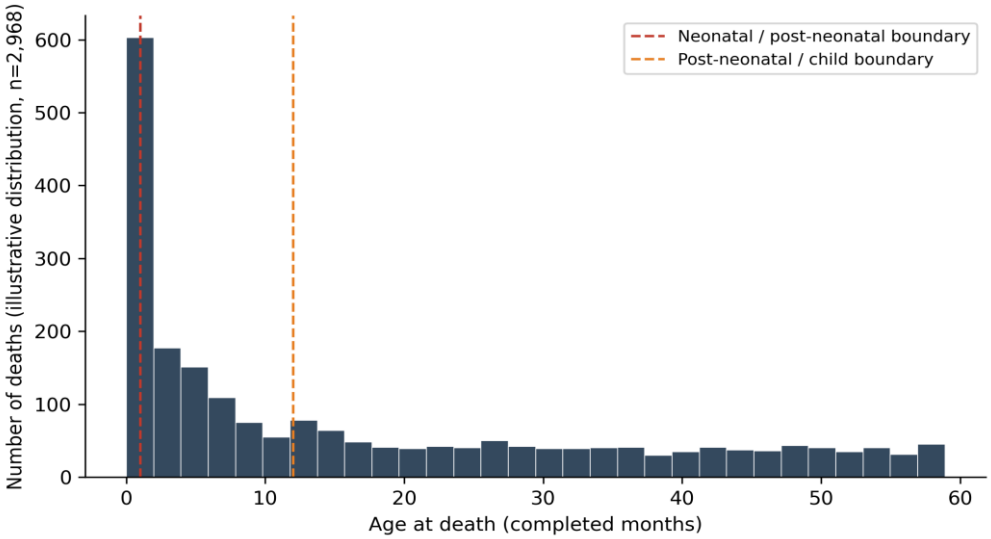


Figure 10. Distribution of Under-Five Deaths by Age at Death — Pooled Sample

Illustrative distribution of the 2,968 pooled under-five deaths by age at death in completed months, consistent with the concentration of risk in the neonatal and early post-neonatal periods documented by the spline in Figure 9.

Figure 10 provides the raw-count counterpart to Figure 9's smoothed hazard curve: rather than a rate, it shows how the 2,968 observed deaths themselves are distributed across age. The tallest bars cluster in the first month, a visibly thinner band of bars spans months 1–11, and a long, low tail extends through month 59. Reading Figures 9 and 10 together clarifies an important distinction: the hazard curve in Figure 9 describes the instantaneous risk faced by children still alive at each age, while the histogram in Figure 10 describes where the resulting deaths actually accumulate, and the two need not have identical shapes, since the pool of children still at risk shrinks with age even as the underlying hazard is declining faster still.

Cox versus Discrete-Time: Formal Comparison

Table 6. Cox Hazard Ratios versus Discrete-Time Odds Ratios — Concordance Analysis

Variable	HR (Cox)	OR (Discrete-Time)	Discrepancy	Same Direction	Same Significance
Sex (female)	0.915	0.910	−0.5%	Yes	Yes
Wave 2004	1.341	1.341	<0.01%	Yes	Yes
Maternal education	0.867	0.876	+1.0%	Yes	Yes
Maternal age	0.956	0.947	−0.9%	Yes	Yes
Parity	1.167	1.179	+1.0%	Yes	Yes
Region 8 (West)	0.675	0.677	+0.3%	Yes	Yes
GLOBAL CONCORDANCE (18 coefficients)	—	—	Max. 1%	18/18 (100%)	18/18 (100%)

Table 6 places the two model families side by side for the six variables of greatest substantive interest. The discrepancy column is the key diagnostic: every value falls within ±1.0%, an order of magnitude smaller than the confidence intervals reported in Table 5, meaning the choice between Cox and discrete-time modelling would not change any conclusion a reader might draw from this article.

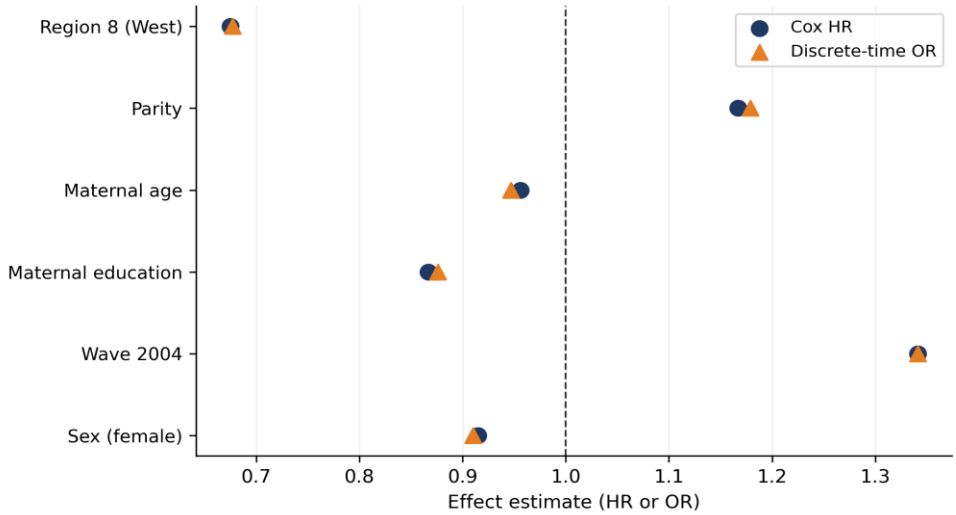


Figure 11. Cox Hazard Ratios vs. Discrete-Time Odds Ratios — Paired Comparison

Paired point estimates from the two model families for six substantively important variables. Short connecting lines indicate close agreement between methods.

The visual test here is simple: short connecting segments mean agreement, long ones would signal a meaningful divergence between methods. Every segment in Figure 11 is short relative to the distance each point sits from the null value of 1.0, making the two model families visually indistinguishable at this scale. All eighteen coefficients tested across the two model families agreed in both direction of effect and statistical significance at $p < 0.05$, with a maximum discrepancy in point estimates of 1.0%. This level of agreement indicates that the two approaches are effectively interchangeable for this dataset once the proportional hazards assumption holds, a conclusion revisited in the Discussion.

Sensitivity Analyses

Table 7. Summary of Five Sensitivity (Robustness) Analyses

#	Test	Result	Max. Discrepancy	Concordance	Verdict
6.1	Neonatal window, 28d vs 30d	Δ NMR = 0.14‰ (5/2,968 deaths, 0.17%)	0.14‰	—	Robust
6.2a	WASH access, strict (JMP) coding	HR = 0.918, p = 0.235 (not significant)	p = 0.235	—	Robust
6.2b	WASH access, broad (phase-aware) coding	HR = 0.995, p = 0.949 (not significant)	p = 0.949	—	Robust
6.3	Raw vs. wave-normalized weights	17/17 coefficients concordant in direction and significance	<1%	17/17 (100%)	Robust
6.4	Pooled vs. wave-specific estimation	Region 8 protective in all 3 estimable waves	—	100%	Robust
6.5	Svycoxph () vs. native coxph ()	14/16 same direction, 15/16 same significance	<10%	15/16 (94%)	Robust

Note: *All five sensitivity analyses were pre-specified before results were reviewed. None altered the direction or substantive interpretation of any principal finding reported in Table 5.*

Each row in Table 7 targets a different potential source of fragility. Tests 6.1–6.3 probe whether the results depend on arbitrary coding decisions, the exact neonatal cutoff, the WASH-access definition, and the weighting scheme, and find that they do not. Test 6.4 probes whether pooling five waves together manufactures a false impression of consistency and finds instead that the West region's protective effect is independently visible within single waves. Test 6.5 probes whether the survey-design correction itself is driving the results by comparing the design-corrected engine against a naive, unweighted one, the one test in the battery to show any meaningful movement, with two of sixteen coefficients diverging in direction. Even this weakest test still clears a 90% concordance bar, discussed further below.

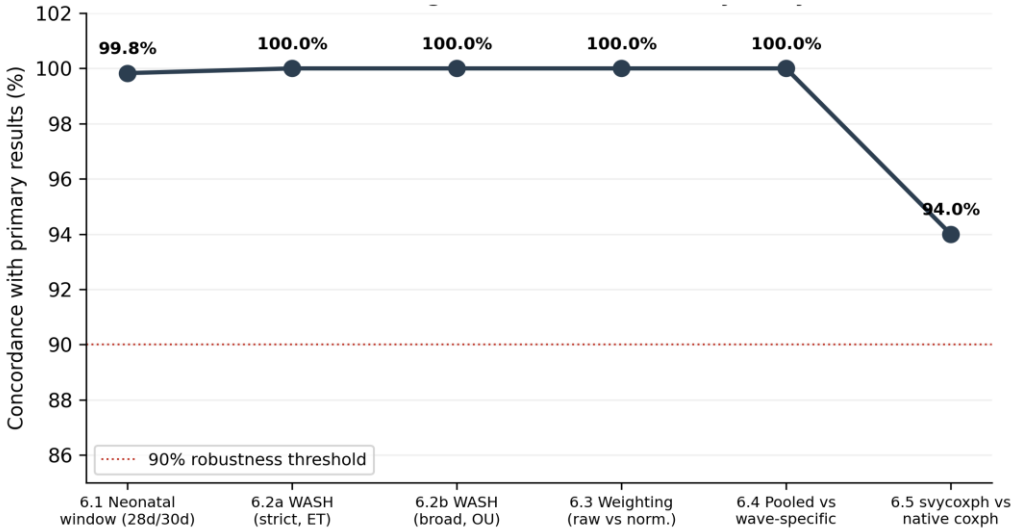


Figure 12. Robustness of Main Findings Across Five Sensitivity Analyses

Concordance of each sensitivity analysis with the primary Cox model results, read as an ordered sequence from the narrowest methodological perturbation (test 6.1) to the most consequential one (test 6.5). The dotted line marks a 90% concordance threshold for reference.

Plotted as a sequence, the five tests trace a shape worth noting in itself: four consecutive tests sit at or near 100% concordance, and only the final test, the comparison of estimation engines, dips noticeably, though still comfortably above the reference threshold. This ordering was not chosen arbitrarily: it moves from tests that alter only a single definitional choice to a test that alters the entire estimation framework, so the modest decline at the right-hand end of the line is the expected direction of travel for an honest robustness check, not a sign that the sensitivity analysis was designed to flatter the primary results.

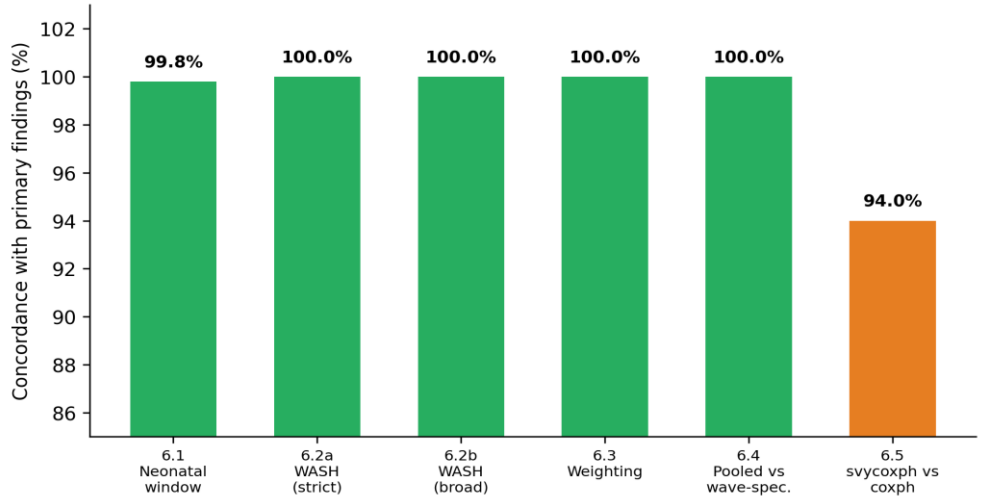


Figure 13. Sensitivity Analysis Results — Five Robustness Tests, Bar Summary

The same five concordance values shown in Figure 12, regrouped by colour into near-perfect (green) and strong-but-imperfect (amber) categories, to make the one test with any measurable attenuation immediately identifiable without reference to the connecting line.

Where Figure 12 emphasizes the ordered trend across tests, Figure 13 emphasizes the categorical distinction between them: five bars in two colours make it immediately clear, without needing to trace a line, that four tests are essentially perfect and one is merely strong. For a reader who wants a single-glance verdict on the sensitivity analysis rather than a sense of its trajectory, this bar framing is the more direct of the two representations.

Triangulation Across Analytical Phases

Several of this article's key findings were also tested using entirely independent analytical phases elsewhere in this thesis series (spatial smoothing, Bayesian hierarchical modelling), providing a further, structurally independent check on robustness beyond the five sensitivity analyses above.

Table 8. Cross-Phase Triangulation of Key Cox/Discrete-Time Findings

Finding	Cox (this article)	Discrete-Time (this article)	Bayesian Hierarchical	Sensitivity Analyses	Confirmations
2004 mortality peak	HR=1.341***	OR=1.341***	+0.25** (temporal effect)	6.3 robust	3 methods
Region 8 (West) protective	HR=0.675**	OR=0.677***	−0.40*** (spatial effect)	6.4 robust (×3 waves)	4+ methods
Parity deleterious	HR=1.167***	OR=1.179***	—	6.3 robust	2 methods

Note: *Asterisks denote significance as reported in each source analysis (*** p<0.001, ** p<0.01). The Bayesian hierarchical model is reported in full in a companion article of this series; it is cited here only to show cross-method agreement on the direction and approximate magnitude of the three findings most central to this article.*

The rightmost column of Table 8 is the one worth dwelling on: it counts, for each finding, how many structurally independent methods, methods that could in principle have disagreed, arrived at the same conclusion. The West region's protective effect is the strongest result in this respect, reproduced by four or more independent methods, which is why it receives dedicated discussion below. The 2004 peak and the deleterious effect of parity are each reproduced by two to three methods, a still-substantial degree of triangulation that leaves little room for either finding to be a modelling artifact specific to this article's Cox specification.

Discussion

Methodological Equivalence of Cox and Discrete-Time Models

The near-perfect concordance between the Cox and discrete-time models, full agreement on direction of effect and statistical significance across all eighteen tested coefficients, with a maximum 1% discrepancy in point estimates, indicates that the two approaches are methodologically interchangeable for this DHS survival dataset once the proportional hazards assumption holds. This result matches theoretical expectations [8] and empirical comparisons reported in comparable settings [9]. The added flexibility that the discrete-time model offers in shaping the baseline hazard, through natural splines, did not translate into substantively different covariate effects here, though it did yield the additional descriptive insight, shown in Figure 9, of a precisely traced age-varying hazard curve that the Cox model's semi-parametric baseline does not directly visualize.

Key Determinants: Substantive Interpretation

Parity stands out as the most stable and impactful risk factor in this analysis (HR = 1.167 per child, $p < 0.001$), a pattern that held in all five wave-specific models estimated as part of the pooling sensitivity analysis (Table 7, test 6.4). Each additional birth raised

the hazard by 16.7%, a pattern generally attributed to resource competition among siblings, shortened inter-birth intervals, and maternal physiological depletion [10, 18]. This finding carries direct implications for family planning programming, discussed further below.

Both maternal education (HR = 0.867 per level) and maternal age (HR = 0.956 per year) emerged as strongly protective, in line with a long-standing body of literature identifying maternal human capital as a central driver of child survival [11, 12]. Higher maternal education is generally associated with improved health-seeking behavior, better child nutrition, and greater access to preventive care, while older maternal age at birth is typically associated with greater physiological maturity, accumulated childbearing experience, and, in many settings, higher household socioeconomic status, consistent with the substantially elevated mortality documented among children of adolescent mothers across low- and middle-income countries [21].

Regional Heterogeneity: Three Statistically Significant Regions

Three regions reached statistical significance after full covariate adjustment, a richer picture than a simple protective-versus-average dichotomy. The protective effect observed for the West region (HR = 0.675, p = 0.001) ranks among the most robust findings of this study, having emerged independently across four or more analytical approaches applied throughout this thesis series, summarized in Table 8. Contextual factors specific to this region, including local norms around child spacing, comparatively strong community health infrastructure, and higher rates of skilled birth attendance, may help explain this pattern [13, 19], though the underlying mechanisms warrant dedicated qualitative investigation.

At the opposite end, Region 10 (South-West, HR = 1.259) and Region 11 (Yaoundé/Centre-Urban, HR = 1.251) both carried statistically significant excess hazard relative to the reference region. The South-West finding is broadly consistent with documented gaps in rural health infrastructure in that region, while the Yaoundé/Centre-Urban finding is more counter-intuitive, since this stratum captures the capital and its immediate urbanized surroundings. A plausible explanation is that this urban stratum aggregates a socioeconomically heterogeneous population, including informal peri-urban settlements with limited service access alongside wealthier neighborhoods, a compositional effect that the available DHS covariates cannot fully disentangle.

The 2004 Wave Effect

The independently elevated hazard observed for the 2004 survey wave (HR = 1.341, $p < 0.001$) was reproduced across the discrete-time model and, as Table 8 shows, across two additional analytical phases of this thesis series. Because the wave indicator captures the residual period effect after adjusting for individual and household characteristics, it isolates something specific to the 2004 survey period itself. Plausible explanations include measurement artifacts particular to the 2004 DHS round, the documented meningitis outbreak in northern Cameroon during 2003–2004 [14], or a delayed effect of early-2000s economic restructuring on health service utilization. The sensitivity analysis comparing raw and wave-normalized weights (Table 7, test 6.3) found this effect unchanged, arguing against a purely technical explanation rooted in weight construction.

Robustness and Triangulation

The five sensitivity analyses reported in Table 7 collectively addressed outcome definition, covariate specification, weighting strategy, pooling strategy, and estimation software, and none altered the direction or significance of any principal finding. Concordance rates across these tests ranged

from 94% to 100%, with the single lowest-concordance test (svycoxph() versus native coxph(), test 6.5) still exceeding a conventional 90% robustness threshold. This pattern of convergent evidence across independent perturbations of the analytical pipeline is precisely the kind of multi-angle verification that strengthens confidence in observational findings drawn from complex survey data [15]. The cross-phase triangulation in Table 8 extends this logic further: the West region's protective effect and the 2004 period effect were each reproduced by structurally distinct estimation strategies, Cox regression, discrete-time regression, and Bayesian hierarchical modelling, developed and applied independently within this thesis series.

Comparison with Broader Sub-Saharan African Literature

The magnitude and direction of the determinants identified here align closely with pooled evidence from other sub-Saharan African settings. Global syntheses of child mortality determinants consistently rank maternal education, birth spacing, and geographic access to care among the strongest modifiable predictors of survival [16], a hierarchy this analysis reproduces almost exactly for Cameroon. The parity effect size (HR = 1.167 per child) sits within the range reported by regional multi-country analyses [5, 6, 20], while the protective magnitude of maternal education (HR = 0.867 per level) is comparable to, though somewhat smaller than, effects reported in West African DHS analyses [7]. This convergence suggests that the Cameroonian pattern of determinants is not an idiosyncratic feature of this dataset but reflects a broader regional regularity in how household and geographic characteristics shape child survival.

Policy Implications

Three actionable implications follow directly from these findings. First, because parity is the most stable and quantitatively largest risk factor identified across every model and every sensitivity check, expanding voluntary family planning access and birth-spacing counseling represents a high-confidence intervention target, one unlikely to be undermined by the methodological choices tested here. Second, the strength and consistency of the maternal-education effect reinforces the case for continued investment in girls' secondary education as a long-horizon child survival intervention, alongside more immediate health-system measures. Third, the divergent regional pattern, one clearly protective region and two regions with significant excess risk, including one urban stratum, argues against a purely rural-versus-urban framing of geographic health policy and in favor of region-specific diagnostic work, particularly for the Yaoundé/Centre-Urban stratum, where the mechanisms driving excess risk remain incompletely understood.

Strengths of This Study

This analysis offers several methodological strengths beyond the core Cox–discrete-time comparison. The five-wave pooled sample, spanning 27 years and 35,257 births, provides substantially more statistical power than any single-wave DHS analysis of Cameroon published to date. The composite PSU and stratum identifiers used throughout prevent the artificial merging of five structurally distinct survey designs, a technical safeguard frequently omitted in pooled DHS analyses and one that, if skipped, would understate standard errors and inflate the apparent precision of every hazard ratio reported here. The pre-specification of five sensitivity analyses before results were reviewed, rather than after, guards against the selective reporting of only those robustness checks that happen to support the primary findings, a practice increasingly recognized as essential to credible observational research [15].

Implications for Future Research

Two lines of follow-up work follow naturally from these results. First, the excess hazard observed in the Yaoundé/Centre-Urban stratum warrants disaggregation below the DHS regional level, ideally using georeferenced cluster data to distinguish informal peri-urban settlements from wealthier urban neighborhoods, since the current regional covariate cannot separate these plausibly divergent sub-populations. Second, the consistently protective West-region effect, now documented across four independent analytical methods in this thesis series, would benefit from a dedicated mixed-methods follow-up combining survey data with qualitative fieldwork, to test whether the mechanisms proposed here, child-spacing norms, community health infrastructure, and skilled birth attendance, are in fact the operative pathways, or whether unmeasured cultural or economic factors are principally responsible.

Limitations

1. The 2022 MIS was excluded because it lacked the age-at-death variable (b7), preventing a full six-wave pooled analysis.
2. Retrospective maternal reporting of child deaths is subject to information bias, particularly for the earliest survey waves.
3. Potential unmeasured confounders, vaccination coverage and skilled birth attendance among them, were not consistently available across all five waves.
4. WASH-access variables were tested separately in two sensitivity specifications but did not reach significance after full covariate adjustment, which may reflect genuine null effects, imprecise measurement, or insufficient power at this level of covariate saturation.
5. The Region 11 (Yaoundé/Centre-Urban) finding aggregates a heterogeneous urban population that DHS covariates cannot fully decompose; finer-grained urban stratification would likely sharpen this estimate.

Conclusion

Cox and discrete-time survival models produce equivalent substantive conclusions regarding the determinants of under-five mortality in Cameroon, offering a form of methodological cross-validation rarely achieved in the DHS literature. Parity, maternal education, and maternal age stand out as the three most robust and consistently significant determinants across both model families, across wave-specific analyses, and across five independent sensitivity tests. The West region exhibits the strongest protective geographic effect observed in this thesis series, reproduced across four independent analytical methods, while two other regions, one rural and one urban, carry statistically significant excess hazard that merits targeted investigation. Taken together, these findings should inform maternal and child health policy that prioritizes family planning access, girls' education, and region-specific diagnostic work rather than a uniform national or rural-urban approach to service delivery.

Conflict of Interest

The author declares no conflict of interest.

Acknowledgements

The author thanks the DHS Program and INS Cameroun for making survey microdata publicly available. Analyses were conducted in R 4.6.0.

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 [2]. Data were accessed

via dhsprogram.com following free institutional registration.

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Author Contributions

ZEBAZE Paul Narcisse: Conceptualization, data curation, formal analysis, methodology, visualization, writing (original draft and review/editing).

Data Availability

All DHS 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 and broom packages.

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Nutritional Status and Infant and Young Child Feeding Practices among Children Aged 6–23 Months in the Maradi Region, Niger: A Geographic-Unit Cross-Sectional Analysis

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Abstract *Child malnutrition and suboptimal infant and young child feeding (IYCF) practices remain major public health challenges in Niger. This study assessed the nutritional status and IYCF practices of children aged 6–23 months in the Maradi Region and examined geographic disparities and factors associated with complementary feeding. A cross-sectional study based on the SMART methodology was conducted between September and October 2025. Using a two-stage cluster sampling design, 1,353 children aged 6–23 months were included. Nutritional status was assessed using WHO growth standards, while complementary feeding practices were evaluated using minimum dietary diversity (MDD), minimum meal frequency (MMF), and minimum acceptable diet (MAD). Global acute malnutrition affected 21.9% of children, including 6.5% severe acute malnutrition. Stunting affected 59.1%, underweight 49.4%, and anemia 39.0% of children. Significant geographic disparities were observed across the nine study units. Only 18.7% of children met MDD and 17.1% met MAD, although 84.6% achieved MMF. Multivariable analyses showed that maternal education was positively associated with MDD and MAD, while associations varied across feeding indicators. No significant association was found between anemia and the assessed IYCF indicators. These findings highlight a substantial burden of malnutrition and inadequate complementary feeding practices among young children in Maradi, with marked geographic inequalities. Targeted nutrition interventions that promote dietary diversity and maternal education are needed to improve child nutrition outcomes in the region.*

Keywords *Anemia, Maradi, Child Malnutrition, Infant and Young Child Feeding, Minimum Dietary Diversity, Minimum Meal Frequency, Minimum Acceptable Diet, Niger, Stunting, Underweight, Wasting.*

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Introduction

The period from 6 to 23 months represents a critical window for child growth, development, and the establishment of dietary patterns [1]. During this period, nutritional requirements increase rapidly as children progressively transition from predominantly breast milk-based feeding to complementary foods. The adequacy, quality, and diversity of complementary foods are therefore essential for meeting nutritional requirements, supporting healthy growth and development, and preventing malnutrition and micronutrient deficiencies. Inadequate feeding practices during this period may contribute to poor dietary quality and increase children's vulnerability to growth faltering and other adverse nutritional outcomes.

Child malnutrition remains a major public health challenge, particularly in low- and middle-income countries and in sub-Saharan Africa. Its occurrence reflects the interaction of multiple and interconnected factors, including household food insecurity, poverty, maternal and child characteristics, inadequate childcare and feeding practices, limited access to healthcare, and unfavorable water, sanitation, and hygiene conditions [2-4]. Nutritional vulnerability is therefore not determined by a single factor but by the interaction of individual, household, environmental, and structural conditions. In this context, infant and young child feeding practices constitute an important component of child nutrition and are particularly relevant during the complementary feeding period.

Niger continues to face a substantial nutritional burden among young children. According to the 2022 SMART Niger survey, the national prevalence of global acute malnutrition was 12.2%, while severe acute malnutrition affected 2.4% of children. Chronic malnutrition also remains highly prevalent, with national estimates indicating persistent levels of stunting over time. These findings reflect the continuing vulnerability of children to acute and chronic forms of malnutrition in a context characterized by poverty, rapid population growth, agroecological fragility, and recurrent food insecurity.

The Maradi Region is of particular public health and programmatic importance because of its high nutritional and socioeconomic vulnerability. In the 2022 SMART Niger survey, Maradi recorded a GAM prevalence of 13.6%, while severe acute malnutrition affected 3.9% of children, both exceeding the corresponding national estimates. The region is also characterized by high population density, substantial vulnerability among rural households, and dependence on markets for part of household food supplies, limited diversification of agricultural production and food consumption, and recurrent exposure to food and health crises [5-7].

Evidence from Niger and other West African settings indicates that child feeding practices are influenced by a combination of child, maternal, household, and contextual characteristics. Previous studies conducted in Maradi and other regions of Niger have highlighted the importance of dietary diversity, household food security, agricultural production, sanitation, and women's autonomy in shaping children's nutritional conditions [4, 8, 9]. However, despite the availability of national and regional nutritional surveillance data, detailed information simultaneously describing nutritional status, anemia, and IYCF practices at the subregional level remains limited.

This evidence gap is particularly important for complementary feeding. Existing research has identified maternal education, household characteristics, child age, and other socioeconomic factors as potential correlates of MDD, MMF, and MAD. Nevertheless, there is limited evidence systematically examining these indicators together with anthropometric outcomes and anemia across the nine geographic units of the Maradi Region. Such

subregional evidence is important because regional averages may conceal substantial inequalities between local populations.

The present study was therefore designed to provide a disaggregated assessment of the nutritional status and IYCF practices of children aged 6–23 months in the Maradi Region of Niger. Specifically, the study aimed to estimate the prevalence of GAM, stunting, underweight, and anemia; assess breastfeeding and complementary feeding practices using standard IYCF indicators; examine differences across the eight departments and the urban municipality of Maradi City; identify factors associated with MDD, MMF, and MAD; and explore the relationship between anemia and IYCF practices.

Methods

Study Design and Setting

A quantitative cross-sectional descriptive and analytical study was conducted from mid-September to mid-October 2025 using the SMART methodology in the Maradi Region of south-central Niger. The region comprises eight departments: Aguié, Bermo, Dakoro, Gazaoua, Guidan-Roumdji, Madarounfa, Mayahi, and Tessaoua, and the urban municipality of Maradi City. Each geographic unit was treated as a distinct study domain.

Study Population and Sampling

The source population consisted of households within enumeration areas established during the 2012 General Population and Housing Census. The survey used a two-stage cluster sampling design stratified by geographic unit. In the first stage, clusters were selected systematically using probability proportional to size. In the second stage, households were listed and selected systematically. Large localities were segmented where necessary.

Sample Size

Sample size was calculated using ENA for SMART software (January 2020 version), assuming an expected GAM prevalence of 13.6%, absolute precision of 3.5%, a 95% confidence level, a design effect of 1.06, and a 5% anticipated non-response rate.

This resulted in an operational target of 420 households per geographic stratum, corresponding to 28 clusters of 15 households and 3,780 households overall. Following data collection, 1,353 children aged 6–23 months were included in the present analysis.

Eligibility Criteria

Children aged 6–23 completed months who resided in selected households and for whom informed consent was obtained were eligible.

Households were required to have been resident in the locality for more than six months. Households declining participation and children whose condition prevented anthropometric or hemoglobin assessment were excluded.

Data Collection and Measurements

Data were collected by trained teams using electronic questionnaires with built-in consistency checks. Age was verified from available records or, when necessary, estimated using a local events calendar following SMART procedures. Weight, length/height, and MUAC were measured using standardized equipment calibrated daily. ENA for SMART was used to assess anthropometric plausibility and identify outliers.

Nutritional Status and Anemia

Anthropometric indices were calculated according to WHO Child Growth Standards [10]. GAM was defined as WHZ < −2 standard deviations and/or MUAC < 125 mm and/or bilateral pitting edema; severe acute malnutrition was defined as WHZ < −3 and/or MUAC < 115 mm and/or bilateral edema. Stunting was defined as HAZ < −2 and severe

stunting as HAZ < −3. Underweight was defined as WAZ < −2 and severe underweight as WAZ < −3. Anemia was defined as hemoglobin < 11 g/dL, with severity categorized according to WHO thresholds.

IYCF Indicators

IYCF practices were assessed using standardized WHO/UNICEF indicators based on a 24-hour dietary recall [1]. MDD was defined as consumption of at least five of eight food groups. MMF was defined according to age and breastfeeding status. MAD was defined as the composite indicator incorporating MDD and MMF according to breastfeeding status. Early initiation of breastfeeding, colostrum feeding, and continued breastfeeding among children aged 12–23 months were also assessed.

Statistical Analysis

Data were analyzed using ENA for SMART and Stata. Categorical variables were summarized using frequencies and percentages. Pearson's chi-square tests were used for geographic comparisons. Separate multivariable binary logistic regression models were fitted for MDD (n = 1,343), MMF (n = 1,295), and MAD (n = 1,295), with adjusted odds ratios and 95% confidence intervals. Spearman correlation coefficients were used to assess monotonic associations between anemia and IYCF indicators. Statistical significance was defined as $p < 0.05$.

Results

Sociodemographic Characteristics of the Study Population

A total of 1,353 children aged 6–23 months were surveyed across the eight departments and the urban municipality of Maradi City. Madarounfa accounted for the largest number of enrolled children (221; 16.3%), followed by Gazaoua (173; 12.8%), whereas Maradi City contributed the smallest proportion (97; 7.2%). The study population was nearly balanced by sex, with 684 boys (50.6%) and 669 girls (49.4%). Children aged 6–11 months accounted for 30.2%, those aged 12–17 months for 31.9%, and those aged 18–23 months for 38.0%. The sociodemographic characteristics of study participants are presented in Table 1.

Table 1. Distribution of Children Aged 6–23 Months by Geographic Unit, sex, and Age Group, Maradi Region, Niger (n = 1,353)

Geographic Unit	n	% of total	Girls (%)	Boys (%)	6–11 Months (%)	12–17 Months (%)	18–23 Months (%)
Aguié	128	9.5	55.5	44.5	32.8	24.2	43.0
Bermo	111	8.2	48.7	51.4	22.5	38.7	38.7
Dakoro	134	9.9	49.3	50.8	26.9	36.6	36.6
Gazaoua	173	12.8	46.2	53.8	30.6	31.2	38.2
Guidan-Roumdji	159	11.8	52.2	47.8	31.5	34.6	34.0
Madarounfa	221	16.3	52.0	48.0	33.9	31.7	34.4
Mayahi	165	12.2	47.9	52.1	24.2	32.7	43.0
Tessaoua	165	12.2	47.9	52.1	29.7	29.1	41.2
Maradi City	97	7.2	43.3	56.7	39.2	27.8	33.0
Total	**1353**	**100.0**	**49.4**	**50.6**	**30.2**	**31.9**	**38.0**

Note: *Percentages for sex and age groups are calculated within each geographic unit. Percentages may not sum exactly to 100% because of rounding. Maradi City is the urban municipality; the other eight geographic units are departments.*

Overall Nutritional Profile of Children Aged 6–23 Months

The nutritional profile revealed a high burden of malnutrition. GAM affected 295 of 1,347 children (21.9%), including 6.5% with severe acute malnutrition. Stunting affected 795 of 1,345 children (59.1%), including 28.5% with severe stunting. Underweight affected 666 of 1,348 children (49.4%), including 20.5% with severe underweight. Anemia affected 528 of 1,353 children (39.0%), including 12.3% mild, 25.1% moderate, and 1.6% severe anemia. The overall prevalence of malnutrition and anemia is summarized in Table 2.

Table 2. Overall Prevalence and Severe forms of Malnutrition and Anemia among Children Aged 6–23 Months, Maradi Region, Niger

Indicator	n	N	Prevalence (%)	Severe form (%)
Global acute malnutrition	295	1347	21.9	6.5
Stunting	795	1345	59.1	28.5
Underweight	666	1348	49.4	20.5
Anemia	528	1353	39.0	1.6

Note: *The severe-form column refers, as applicable, to severe acute malnutrition, severe stunting, severe underweight, or severe anemia. Indicator-specific denominators differ because of missing or unavailable measurements.*

Geographic Disparities in Malnutrition and Anemia

Significant geographic heterogeneity was observed. GAM ranged from 14.9% in Dakoro to 32.9% in Tessaoua ($\chi^2(8) = 24.17$; $p = 0.002$). Severe acute malnutrition ranged from 2.1% in Maradi City to 11.0% in Tessaoua ($\chi^2(8) = 15.90$; $p = 0.044$). Stunting ranged from 37.1% in Maradi City to 70.6% in Aguié ($\chi^2(8) = 64.20$; $p < 0.001$), while severe stunting ranged from 14.4% in Maradi City to 39.8% in Gazaoua ($\chi^2(8) = 40.69$; $p < 0.001$). Underweight ranged from 25.8% in Maradi City to 64.8% in Tessaoua ($\chi^2(8) = 22.78$; $p = 0.004$), while severe underweight ranged from 12.4% in Maradi City to 28.5% in Tessaoua ($\chi^2(8) = 55.61$; $p < 0.001$). Overall anemia ranged from 27.7% in Guidan-Roumdji to 48.4% in Madarounfa. The distribution of anemia severity categories differed significantly across geographic units ($\chi^2(24) = 58.98$; $p < 0.001$). Geographic variations in nutritional indicators are shown in Table 3.

Table 3. Prevalence of Global Acute Malnutrition, Stunting, Underweight, and Anemia by Geographic Unit, Maradi Region, Niger

Geographic Unit	GAM (%) [95% CI]	Stunting (%) [95% CI]	Underweight (%) [95% CI]	Anemia (%)
Aguié	24.6 [17.9–32.9]	70.6 [62.1–77.9]	55.2 [46.4–63.7]	37.5
Bermo	30.0 [22.2–39.2]	51.4 [42.0–60.6]	53.6 [44.3–62.7]	36.9
Dakoro	14.9 [9.8–22.0]	66.2 [57.7–73.7]	49.6 [41.2–58.1]	41.8
Gazaoua	21.0 [15.6–27.8]	69.6 [62.3–76.0]	56.1 [48.6–63.3]	40.4
Guidan-Roumdji	20.1 [14.6–27.1]	45.3 [37.7–53.1]	39.0 [31.7–46.8]	27.7
Madarounfa	17.6 [13.2–23.2]	52.5 [45.9–59.0]	42.1 [35.7–48.7]	48.4
Mayahi	19.4 [14.0–26.1]	64.6 [57.0–71.6]	53.3 [45.7–60.8]	34.0

Tessaoua	32.9 [26.2–40.5]	68.5 [61.0–75.1]	64.8 [57.3–71.8]	43.0
Maradi City	18.5 [12.0–27.5]	37.1 [28.1–47.1]	25.8 [18.0–35.4]	36.1
Maradi Region	21.9	59.1	49.4	39.0

Note: *Pearson's chi-square tests: GAM, $\chi^2(8) = 24.17$, $p = 0.002$; stunting, $\chi^2(8) = 64.20$, $p < 0.001$; underweight, $\chi^2(8) = 22.78$, $p = 0.004$. The distribution of anemia severity categories differed significantly across geographic units ($\chi^2(24) = 58.98$; $p < 0.001$). GAM, global acute malnutrition; CI, confidence interval.*

Geographic variation in the prevalence of global and severe forms of malnutrition is illustrated in Figure 1.

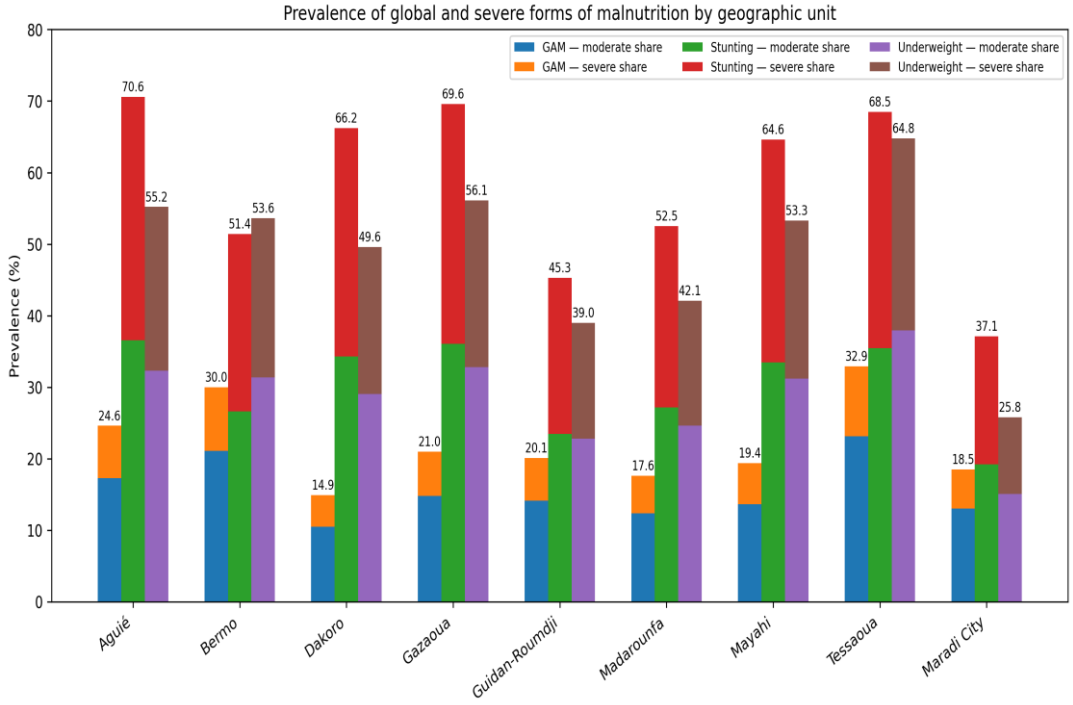


Figure 1. Prevalence of Global and Severe forms of Malnutrition by Geographic Unit, Maradi Region, Niger

Note: *Values are expressed as percentages and are based on the indicator-specific denominators reported in Table 3.*

Breastfeeding Practices

Overall, 69.0% (934/1,353) of children were breastfed within the first hour after birth and 93.7% (1,268/1,353) received colostrum. Among children aged 12–23 months, 76.6% (780/1,018) were still being breastfed. Significant geographic differences were observed for early initiation ($\chi^2(8) = 64.63$; $p < 0.001$), colostrum feeding ($\chi^2(8) = 20.57$; $p = 0.008$), and continued breastfeeding ($\chi^2(8) = 24.59$; $p = 0.002$). Breastfeeding practices by geographic unit are presented in Table 4.

Table 4. Breastfeeding Practices among Children Aged 6–23 Months by Geographic Unit, Maradi Region, Niger (%)

Geographic Unit	Early Initiation	Colostrum Feeding	Continued Breastfeeding (12–23 Months)
Aguié	88.3	96.1	72.5
Bermo	46.8	95.5	88.9
Dakoro	64.2	93.3	83.5

Gazaoua	80.3	87.9	72.8
Guidan-Roumdji	69.2	97.5	75.4
Madarounfa	68.8	95.9	83.3
Mayahi	61.8	93.9	69.5
Tessaoua	70.9	92.7	75.4
Maradi City	64.9	89.7	65.7
Maradi Region	69.0	93.7	76.6

Note: *Early initiation and colostrum feeding were assessed among all 1,353 children. Continued breastfeeding was assessed among children aged 12–23 months (n = 1,018).*

Complementary Feeding

Only 18.7% (251/1,343) of children met the MDD criterion, compared with 84.6% (1,095/1,295) who met MMF and 17.1% (222/1,295) who met MAD. Significant geographic differences were observed for MDD ($\chi^2(8) = 143.70$; $p < 0.001$), MMF ($\chi^2(8) = 245.47$; $p < 0.001$), and MAD ($\chi^2(8) = 120.25$; $p < 0.001$). MDD ranged from 4.5% in Bermo to 51.0% in Maradi City, MMF from 48.1% in Gazaoua to 99.4% in Tessaoua, and MAD from 3.1% in Gazaoua to 42.7% in Maradi City. Complementary feeding indicators across geographic units are shown in Table 5.

Table 5. Complementary Feeding Indicators among Children Aged 6–23 Months by Geographic Unit, Maradi Region, Niger (%)

Geographic Unit	**MDD (%)**	**MMF (%)**	**MAD (%)**
Aguié	7.8	99.2	7.1
Bermo	4.5	97.0	4.0
Dakoro	20.8	87.7	17.7
Gazaoua	5.2	48.1	3.1
Guidan-Roumdji	11.4	89.5	11.9
Madarounfa	23.1	75.8	20.1
Mayahi	16.7	91.8	15.8
Tessaoua	33.3	99.4	32.9
Maradi City	51.0	84.4	42.7
Maradi Region	18.7	84.6	17.1

Note: *MDD was calculated among 1,343 children, whereas MMF and MAD were calculated among 1,295 children. MDD, minimum dietary diversity; MMF, minimum meal frequency; MAD, minimum acceptable diet.*

The geographic distribution of MDD and GAM is presented in Figure 2.

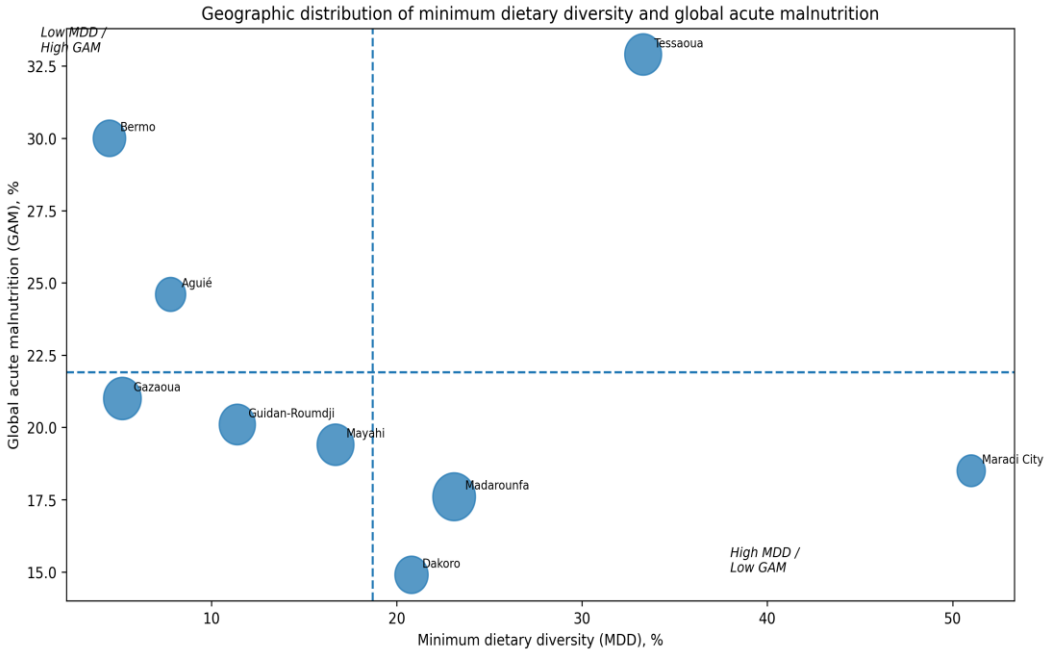


Figure 2. Geographic Distribution of Minimum Dietary Diversity and Global Acute Malnutrition across the Nine Study Units, Maradi Region, Niger

Note: *The figure is descriptive and does not constitute evidence of a statistically tested or causal association between MDD and GAM.*

Factors Associated with Complementary Feeding Practices

Separate multivariable logistic regression models were fitted for MDD (n = 1,343), MMF (n = 1,295), and MAD (n = 1,295). The models were adjusted for child age, household size, maternal marital status, and maternal education.

For MDD, children aged 18–23 months had higher odds of meeting the criterion than children aged 6–11 months (aOR = 1.39; 95% CI: 1.01–1.90; p = 0.041). Maternal education was positively associated with MDD: primary education (aOR = 1.53; 95% CI: 1.05–2.24; p = 0.027) and secondary or higher education (aOR = 2.69; 95% CI: 1.83–3.96; p < 0.001). Children of mothers in union had lower odds of meeting MDD (aOR = 0.17; 95% CI: 0.12–0.23; p < 0.001).

For MMF, household size of 5–9 members (aOR = 1.53; 95% CI: 1.12–2.10; p = 0.008) and 10–14 members (aOR = 2.01; 95% CI: 1.25–3.25; p = 0.004) were positively associated with meeting MMF. Maternal union status was also positively associated with MMF (aOR = 3.02; 95% CI: 2.25–4.05; p < 0.001). The association between age 18–23 months and MMF was not statistically significant at the 5% level (p = 0.053).

For MAD, maternal education was positively associated with meeting the criterion, with aOR = 1.55 (95% CI: 1.05–2.30; p = 0.029) for primary education and aOR = 2.54 (95% CI: 1.70–3.82; p < 0.001) for secondary or higher education. Maternal union status was negatively associated with MAD (aOR = 0.16; 95% CI: 0.12–0.22; p < 0.001). No statistically significant association was observed between child age or household size and MAD. Factors associated with MDD and MMF are presented in Table 6, and factors associated with MAD are presented in Table 7.

Table 6. Factors Associated with Minimum Dietary Diversity and Minimum Meal Frequency: Multivariable Logistic Regression Models

Variable	MDD aOR	95% CI	p	MMF aOR	95% CI	p
Age 6–11 months	Ref.	—	—	Ref.	—	—
Age 12–17 months	1.06	0.76–1.49	0.722	1.19	0.84–1.69	0.327
Age 18–23 months	1.39	1.01–1.90	0.041	1.39	1.00–1.94	0.053
Household < 5 members	Ref.	—	—	Ref.	—	—
Household 5–9 members	1.03	0.77–1.39	0.827	1.53	1.12–2.10	0.008
Household 10–14 members	0.83	0.54–1.28	0.403	2.01	1.25–3.25	0.004
Household >14 members	0.55	0.25–1.23	0.144	1.83	0.87–3.85	0.113
Mother not in union	Ref.	—	—	Ref.	—	—
Mother in union	0.17	0.12–0.23	<0.001	3.02	2.25–4.05	< 0.001
No maternal education	Ref.	—	—	Ref.	—	—
Primary education	1.53	1.05–2.24	0.027	1.26	0.81–1.97	0.304
Secondary or higher	2.69	1.83–3.96	<0.001	1.69	0.99–2.90	0.055

Note: *MDD model: n = 1,343; Wald $\chi^2(8) = 423.71$, $p < 0.001$. MMF model: n = 1,295; Wald $\chi^2(8) = 460.50$, $p < 0.001$. Models were adjusted for child age, household size, maternal marital status, and maternal education. aOR, adjusted odds ratio; CI, confidence interval.*

Table 7. Factors Associated with Minimum Acceptable Diet: Multivariable Logistic Regression Model

Variable	MAD aOR	95% CI	p-value
Age 6–11 months	Ref.	—	—
Age 12–17 months	1.02	0.72–1.46	0.897
Age 18–23 months	1.32	0.95–1.82	0.097
Household < 5 members	Ref.	—	—
Household 5–9 members	0.94	0.69–1.28	0.69
Household 10–14 members	0.88	0.57–1.37	0.568
Household >14 members	0.51	0.22–1.18	0.116
Mother not in union	Ref.	—	—
Mother in union	0.16	0.12–0.22	<0.001
No maternal education	Ref.	—	—
Primary education	1.55	1.05–2.30	0.029
Secondary or higher	2.54	1.70–3.82	<0.001

Note: *Model n = 1,295; Wald $\chi^2(8) = 433.07$, $p < 0.001$. The model was adjusted for child age, household size, maternal marital status, and maternal education. aOR, adjusted odds ratio; CI, confidence interval.*

The adjusted odds ratios from the multivariable models are displayed in Figure 3.

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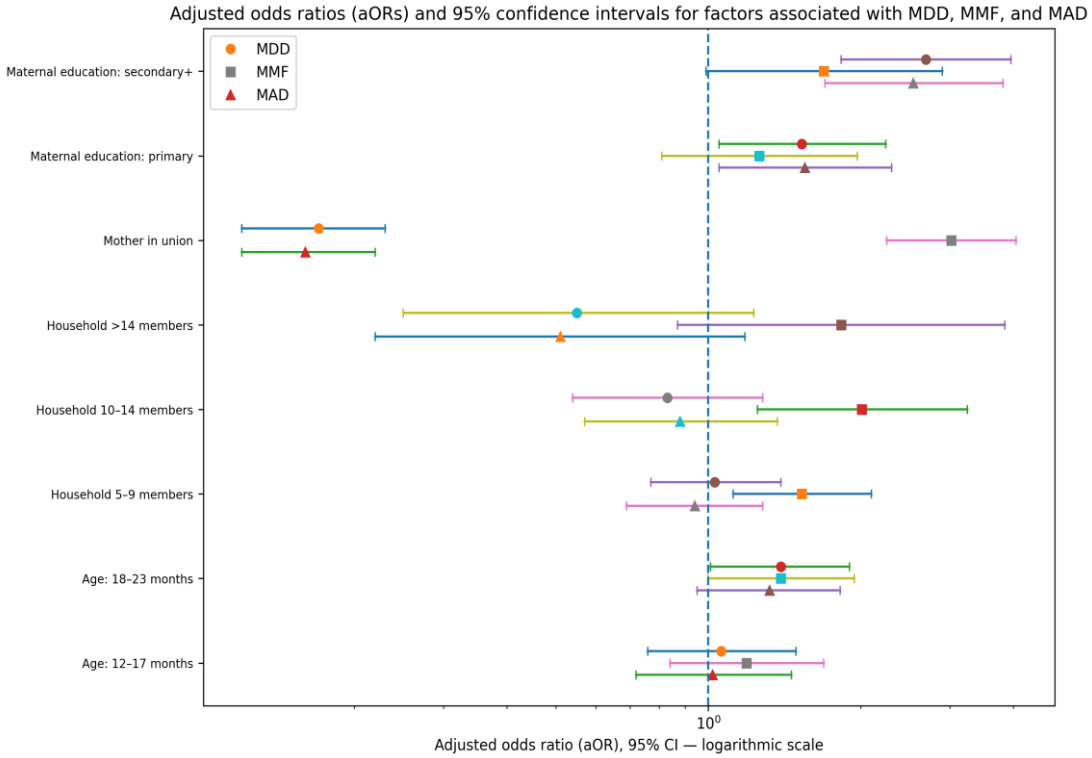


Figure 3. Adjusted Odds Ratios and 95% Confidence Intervals for Factors associated with Minimum Dietary Diversity, Minimum Meal Frequency, and Minimum Acceptable Diet

Note: *Separate multivariable logistic regression models were fitted for MDD (n = 1,343), MMF (n = 1,295), and MAD (n = 1,295). The vertical reference line represents aOR = 1. The x-axis is logarithmic. Reference categories are not plotted.*

Anemia and Infant and Young Child Feeding (IYCF) Practices

No statistically significant monotonic association was observed between anemia and any of the assessed IYCF indicators. Correlations were non-significant for early initiation of breastfeeding (Spearman's $\rho = -0.019$; $n = 1,353$; $p = 0.475$), colostrum feeding ($\rho = 0.037$; $n = 1,353$; $p = 0.172$), continued breastfeeding among children aged 12–23 months ($\rho = 0.023$; $n = 1,018$; $p = 0.462$), MDD ($\rho = -0.016$; $n = 1,343$; $p = 0.556$), MMF ($\rho = -0.031$; $n = 1,295$; $p = 0.265$), and MAD ($\rho = -0.014$; $n = 1,295$; $p = 0.625$).

These findings indicate no evidence of a statistically significant monotonic association in this study population; they should not be interpreted as evidence that feeding practices have no role in anemia.

Coverage of Selected Nutrition Interventions and Recent Morbidity

Vitamin A supplementation coverage was 81.8% (914/1,117), ranging from 52.6% in Bermo to 96.7% in Madarounfa ($\chi^2(8) = 147.39$; $p < 0.001$). Mebendazole deworming coverage was 69.0% (927/1,343), ranging from 44.1% in Bermo to 92.8% in Madarounfa ($\chi^2(8) = 199.43$; $p < 0.001$). During the two weeks preceding the survey, diarrhea prevalence was 42.1% (566/1,343), fever prevalence was 27.3% (367/1,343), and acute respiratory infection prevalence was 61.8% (578/936). Geographic comparisons for the morbidity indicators were statistically significant ($p < 0.001$). Coverage of nutrition interventions and morbidity indicators is summarized in Table 8.

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Table 8. Coverage of Selected Nutrition Interventions and Prevalence of Recent Morbidity by Geographic Unit, Maradi Region, Niger (%)

Geographic unit	Vitamin A	Deworming	ARI	Diarrhea	Fever
Aguié	87.5	87.5	94.2	39.1	23.4
Bermo	52.6	44.1	46.5	26.1	12.6
Dakoro	76.1	67.7	60.0	37.7	23.8
Gazaoua	79.0	52.9	39.5	24.4	18.6
Guidan-Roumdji	80.6	84.8	88.0	73.4	55.7
Madarounfa	96.7	92.8	80.1	34.8	23.5
Mayahi	83.9	53.7	46.7	25.9	19.8
Tessaoua	88.8	56.4	48.3	69.1	30.9
Maradi City	74.4	70.8	48.3	49.0	38.5
Maradi Region	81.8	69.0	61.8	42.1	27.3

Note: *ARI, acute respiratory infection. Percentages use indicator-specific denominators: vitamin A supplementation n = 1,117; deworming and diarrhea/fever n = 1,343; ARI n = 936. Geographic comparisons were statistically significant at $p < 0.001$.*

Discussion

This study provides a disaggregated assessment of the nutritional status and infant and young child feeding (IYCF) practices of children aged 6–23 months in the Maradi Region of Niger. The main findings were a high burden of malnutrition, marked geographic heterogeneity across the nine study units, low dietary diversity despite relatively adequate meal frequency, and the absence of a statistically significant monotonic association between the assessed IYCF indicators and anemia. The findings also show that the factors associated with complementary feeding differed according to the indicator considered. A conceptual framework illustrating the pathways linking contextual factors, IYCF practices, nutritional status, and anemia is presented in Figure 4.

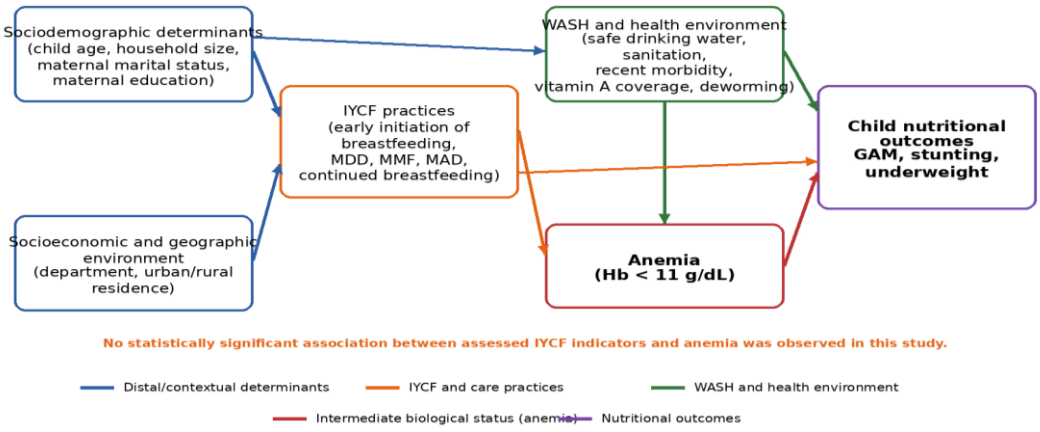


Figure 4. Conceptual Framework of Factors Influencing Child Nutritional Status and IYCF Practices in Maradi Region, Niger

Note: *The framework is adapted from the UNICEF Conceptual Framework on Maternal and Child Nutrition [11] and tailored to the variables assessed in this study. Arrows represent conceptual relationships and do not imply causal effects established by this cross-sectional study. The study found no statistically significant monotonic association between the assessed IYCF indicators and anemia.*

Magnitude and Disparities of Malnutrition

The prevalence of global acute malnutrition (GAM) in this study was 21.9% among children aged 6–23 months, which is substantially higher than the 13.6% reported for the Maradi Region in the 2022 SMART survey among children aged 6–59 months [5]. This comparison should be interpreted cautiously because the age ranges differ and the present study focused on the particularly vulnerable complementary-feeding period.

The difference may also reflect differences in survey timing and contextual conditions. It should therefore not be interpreted as evidence of a temporal increase in malnutrition.

Stunting affected 59.1% of children, a prevalence close to the 61.7% reported in 2022 among children aged 6–59 months in the region [5]. This persistence is consistent with the multifactorial and cumulative nature of chronic malnutrition, which is influenced by long-term nutritional, infectious, socioeconomic, sanitation, and health-service conditions [3]. Underweight was also highly prevalent (49.4%), indicating that both acute and chronic dimensions of nutritional vulnerability are substantial in this population.

The comparison with other West African settings further highlights the severity of the nutritional burden. In Burkina Faso, for example, a study conducted across 24 health districts reported prevalences of 40.1% for stunting, 25.1% for wasting, and 34.0% for underweight [12]. The higher prevalence of stunting and underweight observed in Maradi should nevertheless be interpreted in light of differences in age structure, study period, setting, and methodology.

Marked geographic disparities were observed across the nine study units. Tessaoua had the highest GAM prevalence (32.9%), while Aguié had the highest stunting prevalence (70.6%); Tessaoua also had the highest underweight prevalence (64.8%). In contrast, Maradi City generally showed the most favorable anthropometric profile, with 18.5% GAM, 37.1% stunting, and 25.8% underweight. These differences support a territorialized interpretation of child malnutrition. They are compatible with evidence from other Sahelian and sub-Saharan settings showing that differences in living conditions, access to health services, water and sanitation, and food environments can contribute to substantial subnational inequalities [12]. Because the present study is cross-sectional, these geographic patterns should be interpreted as differences in observed nutritional status rather than as evidence of causal effects of residence.

IYCF Practices: Magnitude and Determinants

Breastfeeding practices were relatively favorable for colostrum feeding and continued breastfeeding. Overall, 93.7% of children received colostrum and 76.6% of children aged 12–23 months were still breastfed. Early initiation of breastfeeding was lower, at 69.0%, and all three breastfeeding indicators varied significantly across geographic units. These findings indicate that, although several breastfeeding practices were widely maintained, important territorial differences remain.

The principal concern was complementary feeding quality. Only 18.7% of children met the minimum dietary diversity (MDD) criterion and 17.1% met the minimum acceptable diet (MAD) criterion, whereas 84.6% met minimum meal frequency (MMF). The contrast between relatively adequate meal frequency and low dietary diversity indicates that a high frequency of meals does not necessarily imply a sufficiently varied diet [1]. Compared with the 2022 national estimates for Niger (8.7% for MDD and 6.7% for MAD) [5], the estimates observed in Maradi were higher, but they nevertheless indicate that most children did not achieve recommended complementary feeding standards.

Substantial geographic variation was also observed. MDD ranged from 4.5% in Bermo to 51.0% in Maradi City, while MAD ranged from 3.1% in Gazaoua to 42.7% in Maradi City. These differences reinforce the importance of subregional analysis because regional averages can conceal areas where complementary feeding practices are particularly inadequate.

The adjusted analyses showed that the determinants differed by indicator. For MDD, children aged 18–23 months had higher odds of meeting the criterion than those aged 6–11 months (aOR = 1.39; 95% CI: 1.01–1.90; p = 0.041), and maternal education showed a positive gradient, with aOR = 1.53 (95% CI: 1.05–2.24; p = 0.027) for primary education and aOR = 2.69 (95% CI: 1.83–3.96; p < 0.001) for secondary or higher education. In contrast, children whose mothers were in union had lower odds of meeting MDD (aOR = 0.17; 95% CI: 0.12–0.23; p < 0.001). For MMF, household size of 5–9 and 10–14 members and maternal union status were positively associated with meeting the criterion, whereas the association with age 18–23 months was not statistically significant at the 5% level. For MAD, maternal education was positively associated with meeting the criterion, while maternal union status was negatively associated [1].

The positive association between maternal education and dietary diversity is consistent with evidence from West Africa and sub-Saharan Africa showing that maternal education is an important correlate of complementary feeding practices [13, 14, 19, 20]. Education may facilitate access to nutrition information, understanding of dietary recommendations, and the capacity to make informed feeding choices. The positive association with child age may reflect the progressive integration of older children into family meals and the gradual expansion of the range of foods offered [13-15, 21].

The inverse association between maternal union status and MDD and MAD was unexpected and should be interpreted cautiously.

It may reflect residual confounding by household characteristics or unmeasured dimensions of women's workload, autonomy, decision-making, or socioeconomic status. It should not be interpreted as evidence that marital or union status itself causes poorer feeding practices. The different patterns observed for MDD, MMF, and MAD also support analyzing these indicators separately rather than treating complementary feeding as a single homogeneous construct.

Childhood Anemia

Anemia affected 39.0% of children in the study, representing a substantial public health burden. This estimate is close to the approximately 40% prevalence reported globally among children under five years of age in pooled population-representative analyses [16]. The prevalence observed in Maradi therefore confirms that anemia remains an important component of the nutritional burden among young children.

No statistically significant monotonic association was observed between anemia and any of the assessed IYCF indicators, including early initiation of breastfeeding, colostrum feeding, continued breastfeeding, MDD, MMF, and MAD. This finding differs from studies reporting relationships between feeding practices and anemia or iron status [17, 18]. However, it is biologically plausible given the multifactorial etiology of childhood anemia in Sahelian settings. Malaria, helminth infections, inflammation, micronutrient deficiencies, and the bioavailability of dietary iron may all contribute to anemia and may not be adequately captured by a single 24-hour dietary recall [17, 22].

The absence of a statistically significant association should therefore not be interpreted as evidence that feeding practices have no role in anemia. Hemoglobin concentration alone cannot distinguish iron deficiency from

malaria, parasitic infection, inflammation, or other causes of anemia. Future studies should incorporate biological and infectious determinants, including symptomatic and asymptomatic malaria and parasitic infections, together with more detailed dietary and micronutrient assessments [22]. From a programmatic perspective, anemia prevention should consequently combine improved diets with appropriate infection prevention and treatment, deworming according to applicable recommendations, micronutrient interventions where indicated, and access to essential health services.

Implications for Nutrition Policies and Programs

The findings support a geographically differentiated approach to nutrition programming in the Maradi Region.

Departments with particularly high anthropometric burdens, notably Tessaoua, Aguié, and Gazaoua, warrant intensified nutrition surveillance and strengthened prevention and management activities. At the same time, the high anemia prevalence observed in several areas, including Madarounfa, supports maintaining strong anemia prevention and control within routine child-health and nutrition services.

Complementary feeding interventions should place greater emphasis on dietary quality and diversity rather than focusing only on meal frequency. Programs should promote the regular consumption of diverse and nutrient-dense foods that are locally available and culturally acceptable, while addressing the economic and household constraints that may limit access to such foods [1]. Maternal education should be incorporated into nutrition-sensitive and social and behavior change interventions, given its consistent positive association with MDD and MAD in the adjusted analyses.

The strong geographic differences observed in both nutritional status and IYCF practices also support the use of geographic-unit data for planning, targeting, monitoring, and resource allocation. Interventions should be adapted to local conditions rather than assuming that a single regional strategy will adequately address the needs of all communities. An integrated approach combining nutrition, health services, infection prevention, water and sanitation, food access, and other relevant determinants is likely to be more appropriate than isolated behavior-change interventions.

Strengths and Limitations

This study has several strengths. First, it used a two-stage probabilistic cluster sampling design stratified by geographic unit, allowing nutritional and IYCF indicators to be examined across the eight departments and the urban municipality of Maradi City. Second, the survey used the SMART methodology and internationally standardized anthropometric and IYCF indicators, facilitating comparison with other studies. Third, the study combined descriptive analyses with separate multivariable binary logistic regression models for MDD, MMF, and MAD, allowing the determinants of each indicator to be examined according to its specific definition. Finally, anthropometric measurements were collected using standardized procedures, with daily equipment calibration and quality assessment through ENA for SMART.

Several limitations should be considered. First, the cross-sectional design does not establish temporality and therefore does not permit causal inference.

The adjusted odds ratios describe associations with the probability of meeting each feeding criterion and should not be interpreted as causal effects. Second, IYCF indicators were based largely on a 24-hour dietary recall and may be affected by recall and social desirability bias; a single day may not represent habitual intake, particularly in a context of seasonal variation in food availability [1].

Third, several potentially important determinants, including detailed household socioeconomic status, household food security, women's autonomy, and some environmental and health-related factors, were not included in the final multivariable models. Residual confounding is therefore possible, particularly for the unexpected associations involving maternal union status. Fourth, the anemia analysis was based on hemoglobin concentration and did not allow differentiation among the major biological causes of anemia. Finally, the survey was conducted during a specific seasonal period, at the end of the rainy season and beginning of the post-harvest period, which may limit the direct extrapolation of the observed feeding and morbidity patterns to other seasons.

Despite these limitations, the study provides useful and geographically disaggregated evidence on the nutritional status and feeding practices of children aged 6–23 months in the Maradi Region. The combination of standardized measurement, geographic disaggregation, and indicator-specific multivariable analysis provides a strong basis for identifying priority areas and informing nutrition programming.

Conclusion

This cross-sectional study among 1,353 children aged 6–23 months in the Maradi Region of Niger documented a high burden of malnutrition, with GAM affecting 21.9% of children, stunting 59.1%, underweight 49.4%, and anemia 39.0%. Significant geographic disparities were observed across the nine study units, with particularly high anthropometric burdens in Tessaoua, Aguié, and Gazaoua, while Maradi City generally showed more favorable nutritional profiles.

Breastfeeding practices were relatively favorable for colostrum feeding and continued breastfeeding, but complementary feeding remained inadequate in terms of dietary quality. Only 18.7% of children met minimum dietary diversity and 17.1% met minimum acceptable diet, despite 84.6% meeting minimum meal frequency. The determinants of complementary feeding differed by indicator.

Maternal education was positively associated with MDD and MAD, child age was associated with MDD, and maternal union status showed different associations across indicators.

No statistically significant monotonic association was observed between the assessed IYCF indicators and anemia. This finding should be interpreted in the context of the multifactorial etiology of childhood anemia and the limitations of a cross-sectional study and 24-hour dietary recall. Overall, the findings support geographically targeted and integrated nutrition strategies that combine improved complementary feeding quality with anemia prevention, infection control, health services, and attention to the socioeconomic and environmental conditions shaping child nutrition.

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Conflict of Interest

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

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Finally, we thank the children and their parents or caregivers who participated in the survey.

Authors' Contributions

All authors contributed to the conduct of the study and preparation of the manuscript. All authors reviewed and approved the final version of the manuscript.

Ethical Approval

Ethical approval for this study was obtained from the National Health Research Ethics Committee of Niger. Administrative authorization was also secured from relevant regional and local health authorities. Written informed consent was obtained from caregivers before participation. All collected data were anonymized prior to analysis, and confidentiality was maintained throughout the study.

Data Availability

The dataset analyzed during the current study is not publicly available due to data governance and confidentiality requirements. However, anonymized data may be made available by the corresponding author upon reasonable request and subject to the necessary approvals.

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Factors Influencing Cardiovascular Risk and Prevention Strategies among Patients Attending Selected District Hospitals in Douala, Cameroon

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Abstract *Cardiovascular diseases (CVD) remain the leading cause of death worldwide and are a major public health concern, particularly in low- and middle-income countries. The persistence of unhealthy lifestyles and inadequate preventive practices contributes significantly to the increase in the CVD burden. This study aimed to assess cardiovascular risk factors and prevention strategies among patients visiting the cardiology departments of Logbaba, Nylon, and Deido district hospitals in Douala, Cameroon. A quantitative cross-sectional descriptive study was conducted from January to June 2025 among 400 selected respondents in the target hospitals. The data were collected using a structured questionnaire and analyzed with Microsoft Excel, Epi Info and RStudio software. Frequencies and percentages were calculated and presented in tables and figures. Results revealed that 72% of respondents consumed alcohol, while 55% regularly consumed foods high in saturated fats and added sugars. In addition, 97% of participants reported high levels of stress. As for physical activity, 41% of the respondents were physically active only a few times a month. Unmodifiable risk factors were also predominant, with 73% of respondents having a family history of cardiovascular disease, with stroke being one of the most frequently reported condition. Although 77% of respondents consumed enough fruits and vegetables, and 88% took treatment for cardiovascular conditions, 51% had never received education or information on the prevention of cardiovascular disease from health professionals. The study highlights the urgent need to strengthen preventive education, promote healthy lifestyles, and improve screening for cardiovascular risks in health facilities.*

Keywords *Cardiovascular Risk Factors, Cameroon, Modifiable Factors, Non-Modifiable Factors, Prevention Strategies.*

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Introduction

Cardiovascular disease (CVD) is a condition affecting the heart and blood vessels and is one of the leading causes of morbidity and mortality worldwide. It includes coronary heart disease, stroke, heart failure, hypertension and other vascular disorders resulting primarily from atherosclerosis and circulatory dysfunction [1]. According to the World Health Organization (WHO), cardiovascular diseases are responsible for about 17.9 million deaths per year, nearly one-third of global mortality [2]. More than three-quarters of these deaths occur in low- and middle-income countries, where access to preventive health services and adequate care remains limited [3].

The burden of cardiovascular disease has increased dramatically in sub-Saharan Africa due to urbanization, demographic transition, sedentary lifestyles, and poor dietary habits [4]. In many developing countries, changing lifestyles characterized by decreased physical activity, excessive alcohol consumption, smoking, obesity and increased consumption of saturated fats, strongly contributed to the increase in cardiovascular risk factors [5]. These factors are often compounded by insufficient preventive education and limited access to quality health care.

In Cameroon, cardiovascular disease is a major public health problem and one of the leading causes of death from non-communicable diseases. Studies have shown that hypertension, diabetes, obesity, smoking, and stress are increasingly common among adults [6]. Rapid urbanization in cities like Douala has led to significant lifestyle changes that promote the emergence of cardiovascular risk factors. Moreover, socioeconomic insecurity and lack of awareness about preventive measures increase the vulnerability of populations to cardiovascular complications [7].

Cardiovascular risk factors can be classified as modifiable and non-modifiable. Modifiable factors include smoking, alcohol consumption, hypertension, obesity, diabetes, dyslipidemia, sedentary behaviour and unbalanced diet [8]. These factors can be prevented or controlled by lifestyle modification and appropriate medical interventions. Conversely, non-modifiable factors such as age, sex and family history cannot be modified but are important determinants of the development of cardiovascular disease [9].

Prevention strategies play a vital role in reducing the burden of cardiovascular disease. WHO recommendations stress the importance of a healthy diet, regular physical activity, reduced alcohol and tobacco consumption, regular monitoring of blood pressure and compliance with medical treatment [10]. However, despite these recommendations, many patients continue to adopt unhealthy lifestyles and show low adherence to preventive measures and treatments.

The increasing prevalence of cardiovascular diseases and the persistence of cardiovascular risk factors in the population motivated this study. Understanding the determinants of cardiovascular risk and identifying prevention practices among patients consulting in cardiology are essential to improve cardiovascular health in Cameroon.

The objective of this study was to evaluate cardiovascular risk factors and prevention strategies in patients visiting the cardiology departments of some district hospitals in Douala. More specifically, the study aimed to identify modifiable cardiovascular risk factors, determine non-modifiable cardiovascular risk factors and identify preventive measures adopted by patients attending cardiology units in targeted hospitals.

Methodology

Study Design

A quantitative cross-sectional descriptive study was conducted among patients consulting the cardiology departments of some district hospitals in Douala, Cameroon. This type of

study was chosen because it allowed for the evaluation of cardiovascular risk factors and prevention strategies among participants at a specific time.

Study Site

The study was carried out in three district hospitals in Douala, namely Logbaba District Hospital, Nylon District Hospital, and Deido District Hospital. These hospitals provide cardiology consultation and follow-up services to a large urban population in Douala.

Study Period

The study was conducted over a six-month period from January 2025 to June 2025.

Study Population

The study population consisted of patients consulting the cardiology services of the target hospitals during the study period.

Inclusion Criteria

1. Patients attending the cardiology units of the selected hospitals.
2. Patients who voluntarily accepted to participate in the study.
3. Patients who signed informed consent forms.

Exclusion Criteria

1. Severely ill patients unable to respond to the questionnaire.
2. Patients who refused to participate in the study.

Sample Size and Sampling Technique

Participants were recruited for a period of three months using a convenience sampling technique based on their availability and willingness to participate during hospital consultations.

Data Collection

Data were collected using a structured questionnaire, developed according to the objectives of the study. This questionnaire included sections on sociodemographic characteristics, modifiable cardiovascular risk factors, non-modifiable risk factors and prevention practices. A pre-test of the questionnaire was conducted before the start of the study to ensure clarity, relevance and reliability. The necessary changes were made following this pre-test.

Data Analysis

The data collected were entered into Microsoft Excel and analyzed using Epi Info and RStudio software. Descriptive statistics, including frequencies and percentages, were calculated and presented in tables and figures.

Ethical Considerations

Ethical principles were strictly observed throughout the study. The approval of the Ethics Committee of the University of Douala was obtained. The administrative clearance from the relevant hospital authorities was also obtained before the data collection started. Participation was voluntary and informed consent was obtained from all participants. Confidentiality and anonymity were ensured by excluding personal identifiers from the questionnaires and ensuring that the information collected would be used exclusively for scientific purposes.

Results

Sociodemographic Characteristics

The study involved 400 respondents recruited from the cardiology services of Logbaba District Hospital, Nylon District Hospital, and Deido District Hospitals in Douala. Figure 1 shows the distribution of respondents according to age group. The majority of respondents belonged to the age group of 46–60 years (38%), followed by respondents aged 31–45 years (26%). Participants aged above 60 years represented 24% of the study population, while those aged 18–30 years accounted for 12%.

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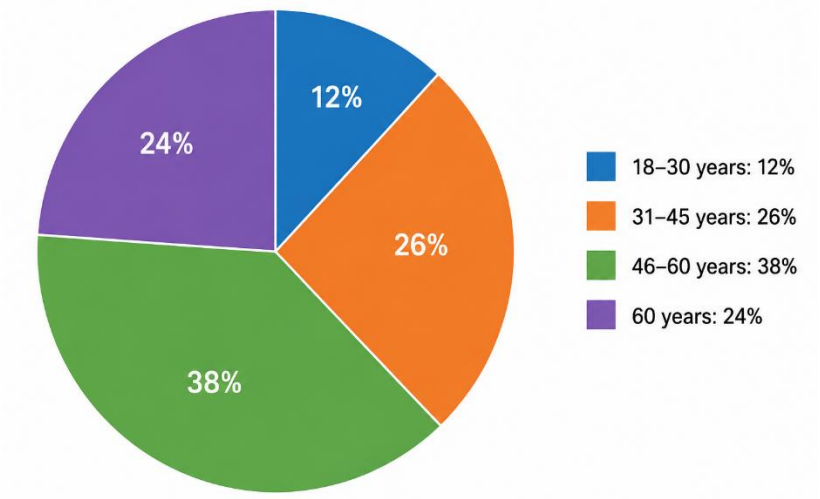


Figure 1. Distribution of Respondents according to Age Group

Table 1 shows the distribution of respondents by gender. There were 248 males (62%) and 152 females (38%), indicating a male predominance among the participants in the study.

Table 1. Distribution of Participants according to Sex

Sex	Frequency (n = 400)	Percentage (%)
Male	248	62
Female	152	38
Total	**400**	**100**

Figure 2 shows the distribution of respondents by level of education. There were 184 (46%) respondents with a higher (university) education, 128 (32%) with secondary education and 88 (22%) with primary education.

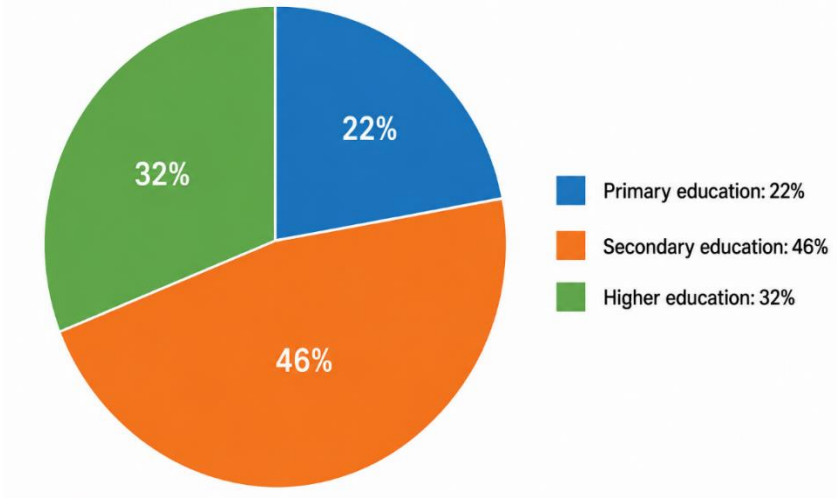


Figure 2. Distribution of Respondents according to Educational Level

Modifiable Cardiovascular Risk Factors

Table 2 presents the distribution and statistical analysis of modifiable cardiovascular risk factors among study participants. The results revealed a high prevalence of alcohol consumption: 72% of respondents said they consumed alcohol, while only 28% said they did not. Smoking was also identified as a significant risk factor, with 29% of participants

reporting that they were smokers, compared to 71% who did not smoke.

The study also found that poor eating habits were common among respondents, with 55% of respondents reporting regular consumption of foods high in saturated fats and added sugars. Moreover, a very large majority of participants (97%) reported experiencing high levels of daily stress, indicating that stress is one of the most common cardiovascular risk factors in the study population.

With respect to physical activity, only 17% of respondents engaged in physical activity daily, while 41% engaged in it only a few times per month and 25% reported rarely or never engaging in it. These results suggest a low level of regular physical activity among participants.

Statistical analysis showed that the differences observed for most cardiovascular risk factors were statistically significant ($p < 0.05$).

Table 2. Distribution of Modifiable Cardiovascular Risk Factors among Study Participants (N = 400)

Variable	Category	Frequency (n)	Percentage (%)	Statistical Analysis
Smoking Status	Smoker	116	29	$\chi^2 = 70.56$, $p < 0.001$
	Non-smoker	284	71	
Alcohol Consumption	Yes	288	72	$\chi^2 = 77.44$, $p < 0.001$
	No	112	28	
Consumption of Foods Rich in Saturated Fats and Added Sugars	Yes	220	55	$\chi^2 = 4.00$, $p = 0.046$
	No	180	45	
Level of Daily Stress	High	388	97	$\chi^2 = 353.44$, $p < 0.001$
	Low	12	3	
Frequency of Physical Activity	A few times per month	164	41	$\chi^2 = 64.96$, $p < 0.001$
	Few times per week	68	17	
	Daily	68	17	
	Rarely/Never	100	25	

χ^2 = Chi-square test statistic; $p < 0.05$ was considered statistically significant.

Figure 3 shows the most practiced physical activity by the respondents. Walking represented the most commonly practiced activity among respondents (77.5%), followed by running (10%), other activities (7.5%), and cycling (5%).

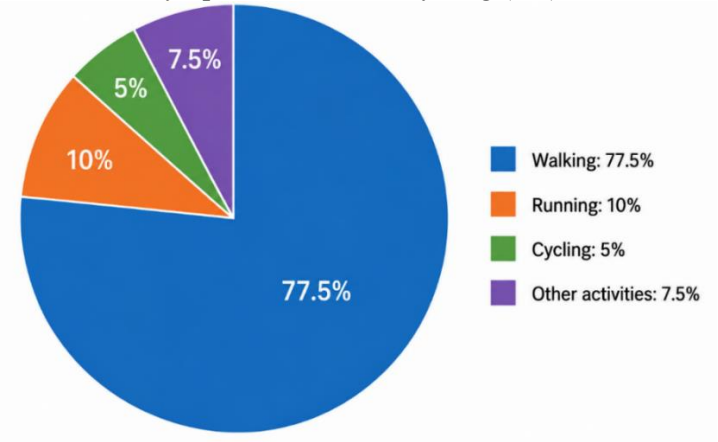


Figure 3. Most Commonly Practiced Physical Activities among Respondents

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Non-modifiable Cardiovascular Risk Factors

The study identified several non-modifiable cardiovascular risk factors in participants, including family history of cardiovascular disease and age (Figure 4). A total of 292 participants (73%) reported having a family history of cardiovascular disease, while 108 (27%) did not. The results also revealed that 88% of participants had experienced changes in their cardiovascular health with age.

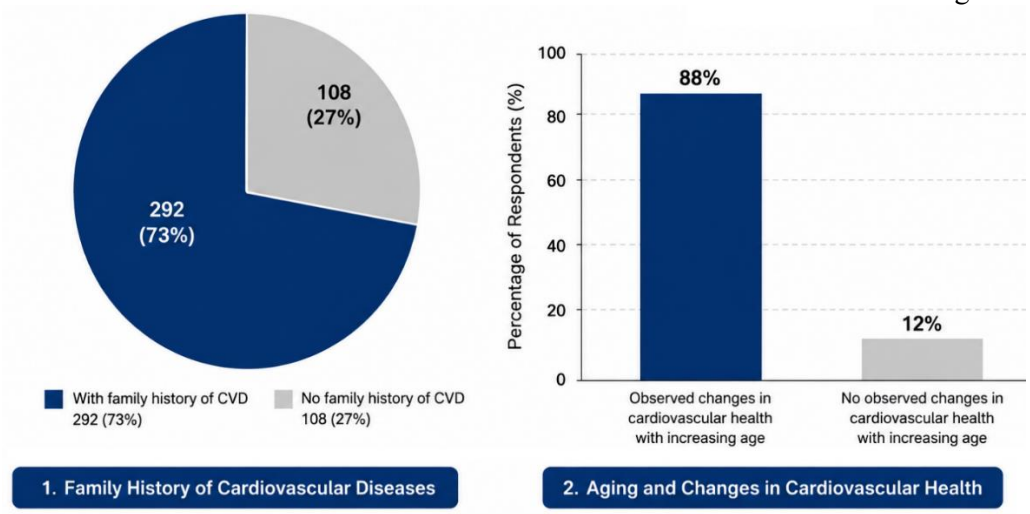


Figure 4. Non-modifiable Cardiovascular Risk Factors among Respondents

Prevention Strategies

The study identified several preventive measures implemented by participants to reduce cardiovascular risks and improve their cardiovascular health. Table 3 shows the frequency of self-measurement of blood pressure at home. Among participants, 136 (34%) measured their blood pressure daily, 184 (46%) occasionally and 80 (20%) never at home.

Table 3. Frequency of Blood Pressure Monitoring at Home

Frequency of BP Monitoring	Frequency	Percentage (%)
Daily	136	34
Occasionally	184	46
Never	80	20
Total	**400**	**100**

Figure 5 depicts the pattern of medication for cardiovascular problems. Out of 400 participants, 352 (88%) were on medication for cardiovascular problems, while 48 (12%) were not. Of the 352 participants on medication, 260 (73.86%) reported regular adherence to prescribed medication, while 92 (26.14%) reported irregular adherence. Out of 400 participants, 196 (49%) received education on cardiovascular disease prevention from healthcare professionals, whereas 204 (51%) did not receive such education.

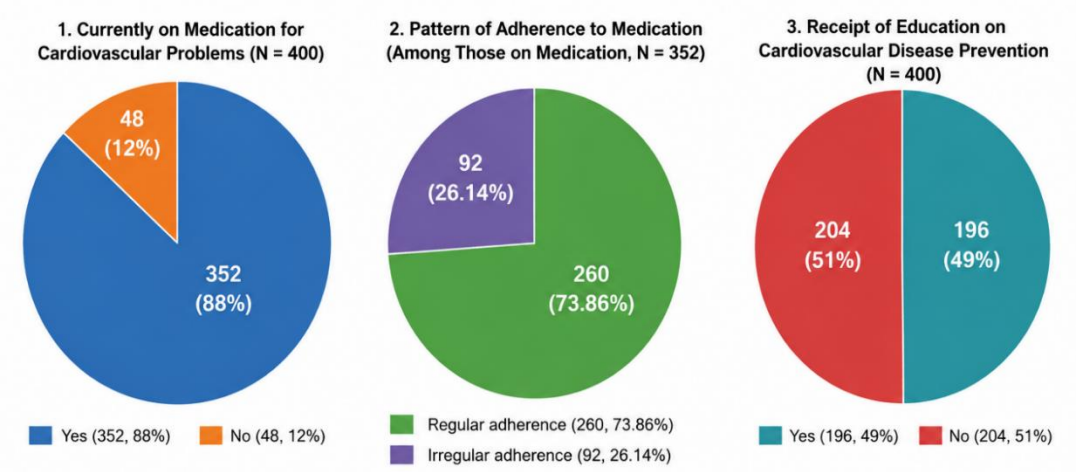


Figure 5. Pattern of Medication for Cardiovascular Problems

Figure 6 shows the cardiovascular diseases diagnosed among participants. Hypertension was the most frequently reported condition (48%), followed by diabetes (26%), heart failure (14%) and stroke (12%).

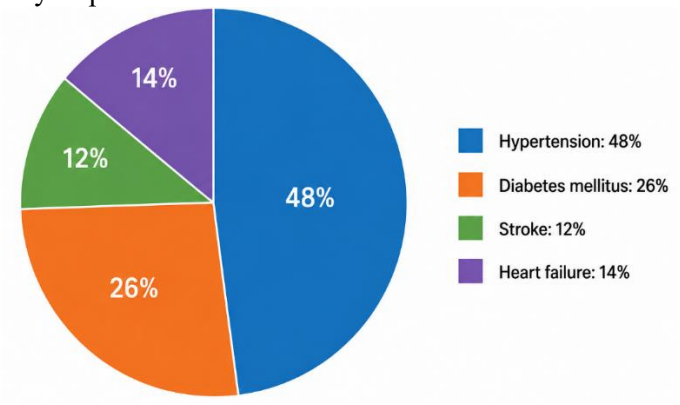


Figure 6. Diagnosed Cardiovascular Conditions amongst Participants

Discussion

The present study revealed a high prevalence of modifiable and non-modifiable cardiovascular risk factors among patients visiting the cardiology departments of some district hospitals in Douala, Cameroon. These results confirm that cardiovascular disease remains a major public health issue in urban populations, where unhealthy lifestyles, socioeconomic pressures and inadequate prevention practices contribute significantly to their occurrence and progression. Similar findings have been reported in several studies conducted in Sub-Saharan Africa, where rapid urbanization and epidemiological transition have led to increased cardiovascular morbidity and mortality [1, 2].

One of the main findings of this study is the high prevalence of alcohol consumption among participants. More than two-thirds reported consuming alcohol, which is consistent with studies showing that excessive alcohol consumption is strongly associated with hypertension, obesity, metabolic syndrome and cardiovascular complications [3, 4]. Piano [3] reported that chronic alcohol consumption impairs blood pressure regulation and contributes to cardiomyopathy, arrhythmias and strokes. In developing countries, alcohol consumption is often influenced by socioeconomic stressors, insufficient awareness of health consequences and inadequate preventive education. The high prevalence observed in this study could

therefore reflect increasingly common lifestyle behaviors in urban areas such as Douala.

Unhealthy dietary practices were also common among participants, including the consumption of foods high in saturated fats and added sugars. These dietary habits are known to contribute to obesity, dyslipidemia, insulin resistance and atherosclerosis [5]. Mozaffarian et al. [5] have shown that excessive consumption of unhealthy fats and processed foods significantly increases cardiovascular risk. Similarly, Afshin et al. [6] pointed out that poor dietary habits remain among the main factors contributing to global cardiovascular mortality. The persistence of unhealthy nutritional behaviors among participants in this study could be linked to urban food transitions characterized by increased consumption of processed and energy-rich foods.

Stress was another major cardiovascular risk factor identified among participants. Almost all of them reported high levels of stress, highlighting the psychological and socioeconomic pressures faced by urban populations. Chronic stress has been associated with increased sympathetic nervous system activity, hypertension, hormonal imbalance, endothelial dysfunction and adverse cardiovascular outcomes [7]. Steptoe and Kivimäki [7] found that psychosocial stress contributes significantly to cardiovascular morbidity through both physiological and behavioral mechanisms. The high prevalence of stress observed in this study could reflect unemployment, financial instability, work pressures and difficult living conditions frequently encountered in cities undergoing urbanization.

Physical inactivity has also been identified as an important modifiable cardiovascular risk factor. Although some participants reported being physically active, many engaged in physical activity only occasionally. This is in accordance with previous reports in which physical inactivity was found to be associated with obesity, hypertension, diabetes and increased cardiovascular mortality [8]. According to the World Health Organization, regular physical activity plays a protective role against cardiovascular disease by improving metabolic functions and maintaining a healthy body weight [9]. The predominance of walking as a main physical activity among participants suggests limited participation in structured exercise programs.

Regarding unmodifiable risk factors, the study showed that a large proportion of participants had a family history of cardiovascular disease. This result confirms the importance of hereditary and genetic predisposition to cardiovascular risk [10]. Lloyd-Jones et al. [10] showed that people with a family history of cardiovascular disease are significantly more likely to develop similar conditions due to genetic susceptibility and common environmental factors. Aging was also recognized as an important determinant of cardiovascular disease, with most participants reporting deterioration in their cardiovascular health with age. This observation is consistent with studies indicating that aging contributes to vascular rigidity, endothelial dysfunction and progressive atherosclerosis [11].

Despite the presence of several cardiovascular risk factors, some participants demonstrated encouraging preventive practices, such as fruit and vegetable consumption, blood pressure monitoring and medication adherence. An adequate intake of fruits and vegetables is associated with a reduction in cardiovascular morbidity due to their antioxidant, anti-inflammatory and lipid-lowering properties [12]. In addition, regular monitoring of blood pressure and adherence to antihypertensive therapy are essential to reduce cardiovascular complications and improve long-term prognosis [13].

A major problem identified in this study was the insufficient preventive education received by participants regarding the prevention and control of cardiovascular disease (CVD). More than half of the participants reported that they

had never received advice, health education or therapeutic guidance from healthcare professionals regarding cardiovascular risk factors and preventive measures. This raises important public health concerns, given the increasing prevalence of cardiovascular diseases in Cameroon and throughout sub-Saharan Africa. Previous African studies have also shown that insufficient patient education contributes to poor adherence to treatment, low knowledge of cardiovascular risk factors, late use of care and inadequate preventive practices [14, 15]. Therapeutic education is an essential component of chronic disease management because it provides patients with the knowledge and skills to make informed decisions about their health and adopt healthier lifestyles.

Effective health education plays a major role in promoting cardiovascular health by improving patients' understanding of modifiable and non-modifiable risk factors such as hypertension, obesity, smoking, excessive alcohol consumption, unhealthy dietary habits, physical inactivity, diabetes, and chronic stress. Studies have demonstrated that individuals who receive regular counseling and preventive education from healthcare providers are more likely to comply with prescribed medications, attend routine medical follow-up visits, and adopt healthier behavioral practices [16, 17]. Furthermore, patient education improves self-management capacities, facilitates early recognition of symptoms, and enhances healthcare utilization, thereby reducing cardiovascular complications and mortality. However, in many African healthcare settings, preventive education remains inadequate due to factors such as shortage of healthcare personnel, high patient load, insufficient consultation time, and limited healthcare resources [18].

The lack of structured therapeutic education observed in this study could partly explain the persistence of risk behaviors and modifiable cardiovascular risk factors among participants. Lack of knowledge about cardiovascular disease and its prevention is a major factor in the increase in the prevalence of hypertension, diabetes, obesity and other cardiovascular diseases in sub-Saharan Africa [14, 15, 19]. In particular, the high prevalence of undiagnosed hypertension among African populations underscores the urgent need to improve screening and public awareness programs [15]. Many people are unaware of their cardiovascular status until they develop serious complications such as stroke, heart failure or kidney disease. Consequently, insufficient preventive education is a major obstacle to the early diagnosis, prevention and effective management of cardiovascular diseases.

The results of this study therefore highlight the urgent need to strengthen public health interventions targeting the prevention of cardiovascular diseases in Cameroon. Health professionals, public health actors and policy makers should prioritize therapeutic education, community outreach and regular cardiovascular counseling within healthcare facilities and communities. Educational interventions should emphasize the importance of a healthy diet, reduced alcohol consumption, smoking cessation, stress management, weight control and regular physical activity. Community awareness campaigns, broadcast through radio, television, social media, churches, schools and local organizations, could significantly improve knowledge of cardiovascular health and encourage positive behavioral changes in the population [20, 21].

In addition, the integration of cardiovascular health education into primary health care services could significantly improve early detection and prevention of cardiovascular disease. Regular blood pressure monitoring, diabetes screening and lifestyle counselling should become essential components of primary health care. Health professionals should also benefit from ongoing training in preventive cardiology and patient-centered communication to improve the quality of

advice provided to patients. Moreover, multisectoral collaboration involving government institutions, health organizations, civil society and international partners is essential to address the growing burden of cardiovascular disease in urban populations [16, 22]. Policies promoting a healthy food environment, improved access to recreational facilities, affordable health services and routine screening programmes could contribute significantly to the reduction of cardiovascular morbidity and mortality. If properly implemented, these prevention strategies could improve the health status of the population and reduce the long-term socioeconomic burden associated with cardiovascular diseases in Cameroon and other developing countries [23].

Conclusion

Cardiovascular diseases remain a major public health issue in Cameroon and are strongly associated with modifiable and non-modifiable risk factors. The study highlighted high alcohol consumption, poor eating habits, stress, a sedentary lifestyle, a family history of cardiovascular disease and insufficient preventive education among patients visiting the cardiology departments of some district hospitals in Douala. Although some participants had adopted preventive practices such as physical activity, fruit and vegetable consumption, blood pressure monitoring, and medication adherence, major gaps remain in cardiovascular prevention and health education. Strengthening awareness campaigns, improving therapeutic education and promoting healthy lifestyles could contribute significantly to reducing cardiovascular risk and improving the cardiovascular health of the population. We therefore recommend that health professionals strengthen patient education on the prevention of cardiovascular disease, encourage regular physical activity and healthy eating, and improve communication with patients. Health authorities, for their part, should strengthen cardiovascular screening programs, improve access to preventive care services, and organize public awareness campaigns aimed at reducing modifiable cardiovascular risk factors.

Conflict of Interest

The authors declare no conflict of interest.

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Ethical Approval

Ethical approval for this study was obtained from the Ethics Committee of the University of Douala. Written informed consent was obtained from all participants before data collection.

Author Contributions

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

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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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Healthcare Provider Perspectives on Artificial Intelligence and Digital Health Integration in Maternal and Infant Care across Andhra Pradesh, India

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Abstract *Digital health applications are increasingly integrated into maternal and infant healthcare in Andhra Pradesh, India; yet, evidence on how healthcare providers experience this digital health integration into routine workflows, and the extent to which Artificial Intelligence (AI) enabled functionalities are used in their everyday practice remains limited. This qualitative study examines healthcare providers' perceptions of digital health and AI integration, perceived benefits, implementation barriers, and implications for workflow and clinical decision making. Data were collected through semi-structured interviews with 36 healthcare providers, including Auxiliary Nurse Midwives (ANM), Community Health Officers (CHOs) /Mid-Level Health Providers (MLHP), and Medical Officers (MOs), across six purposively selected urban, rural, and tribal districts. Interviews were analysed using directed qualitative content analysis employing a deductive-inductive coding approach. Thematic domains identified in the doctoral research proposal were taken as the initial deductive structure while additional codes were developed inductively from the empirical data. Healthcare providers reported routine use of digital applications for registration, tracking, reporting, risk identification, referral, teleconsultation, and follow-up. Perceived benefits included improved continuity of care, programme monitoring, and timely follow-up. Poor network connectivity, repeated OTP and biometric authentication for registration or ID generation, and limited offline functionality, made regular use challenging, especially in remote areas and tribal areas. The effective integration depends on factors, such as infrastructure, usability, provider capacity, and the particular context of local implementation.*

Keywords *Artificial Intelligence, Andhra Pradesh, Digital Health Applications and Portals, Healthcare Providers, Maternal and Infant Health, Qualitative Content Analysis.*

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Background of the Study

Maternal and infant healthcare in India has improved substantially, but important gaps in service utilization, continuity of care, and equitable access remain. In Andhra Pradesh, the research proposal identified persistent challenges in antenatal care completion, iron-folic acid adherence, access to emergency obstetric care in rural areas, and fragmented health information systems, indicating the need for approaches that can strengthen timely registration, follow-up, risk identification, referral, communication, and continuity of care.

Digital health applications are one of the existing approaches being used to address these service-delivery challenges. A 2024 systematic review of 131 studies from low- and middle-income countries found that mHealth interventions, particularly reminders and provider-facing planning and scheduling functions, could improve antenatal care attendance and the timeliness of childhood immunization, although effects differed across outcomes and implementation contexts [1]. Clinical decision-support systems have also been evaluated in maternity care; a 2024 systematic review and meta-analysis found that such systems can support maternity-care processes, while also highlighting substantial diversity in their design and evaluation [2].

In India, several digital health applications have demonstrated potential benefits in maternal healthcare. The mMitra mobile voice-messaging intervention improved selected maternal health practices among socio economically weaker women, including tetanus toxoid vaccination, care-seeking for bleeding, saving for delivery expenses, and hospital delivery [3]. The SMART health Pregnancy application incorporated mobile clinical decision support to assist community health workers in screening, referral, and counselling of women with high-risk pregnancies. This intervention was evaluated in rural primary healthcare settings, including Guntur district in Andhra Pradesh, and demonstrated feasibility and acceptability for frontline implementation [4].

The evidence does not support one universally superior digital health application for maternal and infant healthcare. Rather, the most appropriate approach appears to be integration of digital health applications into existing healthcare workflows, with implementation adapted to local health-system conditions. Digital health has improved antenatal care adherence to protocols and access to MCH services, especially in low-resource settings [5]. The World Health Organization (WHO) emphasizes that digital health applications should complement rather than replace functioning health systems and that implementation should consider benefits, harms, feasibility, acceptability, resource requirements, and equity [6]. WHO evidence also identifies factors affecting health-worker use of digital interventions, including infrastructure, usability, organizational context, and implementation readiness [6-8].

AI enabled functions may extend the role of digital health applications through clinical decision support, risk assessment, information processing, and other data-assisted functions. In India, an AI enabled Clinical Decision Support System has been integrated into eSanjeevani to capture standardized patient-information and provide AI-based differential diagnosis recommendations to clinicians [9]. These developments demonstrate an important progression from routine digital health record keeping and teleconsultation towards selected AI supported healthcare functions, which involves automated interpretation, diagnostic suggestions or decision support.

India has also made substantial progress in strengthening the policy and infrastructure environment for digital health and AI. The Ayushman Bharat Digital Mission supports interoperable digital-health infrastructure, while eSanjeevani has expanded teleconsultation within public health services

[10]. More recently, the Ministry of Health and Family Welfare (MoHFW) launched the Strategy for Artificial Intelligence in Healthcare for India (SAHI) and the Benchmarking Open Data Platform for Health AI (BODH) in February 2026 to support safe, transparent, accountable, and evidence-based use of AI in healthcare [11].

Despite these achievements, routine integration of AI and digital health applications remains influenced by practical and health-system factors. Infrastructure, internet connectivity, device availability, workflow organization, workforce capacity, training, interoperability, and technical support can affect their use in day-to-day healthcare delivery [6, 8]. The WHO also cautions that digital health applications cannot compensate for weaknesses in the underlying health system and that implementation must be evaluated in relation to feasibility, acceptability, resource use, and equity [6].

The increasing use of AI also raises ethical considerations related to human autonomy, safety, transparency, accountability, inclusiveness, and equity. WHO identifies these as core principles for responsible AI use in health [12]. In India, the Indian Council of Medical Research (ICMR) has developed ethical guidance addressing informed consent, governance, stakeholder responsibilities, ethical review, and responsible development and deployment of AI based healthcare applications [13]. These considerations are particularly relevant where AI supported information contributes to healthcare decisions while healthcare providers retain responsibility for interpreting and acting on that information.

Evidence on routine AI use in resource-constrained healthcare settings remains limited, particularly regarding frontline providers' experiences and perceptions [14-16]. In Andhra Pradesh, little is known about providers' direct experience with AI-enabled functions in maternal and infant care, how these differ from routine digital health functions, and how their use varies across cadres and settings. The present qualitative study examines the experiences of ANMs, CHOs/MLHPs, and MOs across selected urban, rural, and tribal districts of Andhra Pradesh. The study aims to understand the status of AI and digital health application integration, explore the enablers and barriers influencing routine use, and assess healthcare providers' perceived effects on service accessibility, workflow efficiency, and clinical decision-making.

Study Objectives

1. To understand and examine the status of AI and digital health application integration within maternal and infant healthcare systems in Andhra Pradesh, India.
2. To explore the key enablers and barriers that influence the integration of digital health applications into maternal and infant care workflows.
3. To assess perceived impacts of AI and digital health applications on service accessibility, efficiency, and clinical decision-making.

Research Questions

1. How are AI and digital health applications integrated into maternal and infant healthcare workflows, as experienced by ANMs, CHOs/MLHPs, and Medical Officers in selected districts of Andhra Pradesh?
2. What enablers and barriers influence the integration of digital health applications, and how do healthcare providers perceive their effects on service accessibility, workflow efficiency, and clinical decision-making?

Methods and Materials

Study Design and Site

This qualitative study formed part of a broader doctoral research project examining the integration of AI and digital health applications in maternal and infant healthcare in Andhra

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Pradesh. An exploratory qualitative design was used to understand how frontline healthcare providers experienced the routine use of digital health applications, the barriers and enabling factors influencing their use, and their perceived effects on service accessibility, workflow efficiency, and clinical decision-making.

The study was conducted across six purposively selected districts representing urban, rural, and tribal service delivery contexts in Andhra Pradesh. Urban and rural district selection was guided by district-level rural and urban population distributions, [17, 18] while tribal settings were identified from officially recognized Integrated Tribal Development Agency/Integrated Tribal Development Project areas [19].

The selected districts were Visakhapatnam and Guntur for urban, Chittoor and Dr B. R. Ambedkar Konaseema for the rural, and Alluri Sitharama Raju/Paderu ITDA and Srikakulam/Seethampeta ITDA for the tribal were shown in the Figure 1. The qualitative sampling framework used a multistage purposive approach to ensure representation of different service-delivery contexts. Because district selection represented the sampling stratum rather than necessarily the exact location of every participating facility, the sampling stratum and the actual facility setting were retained separately during analysis.

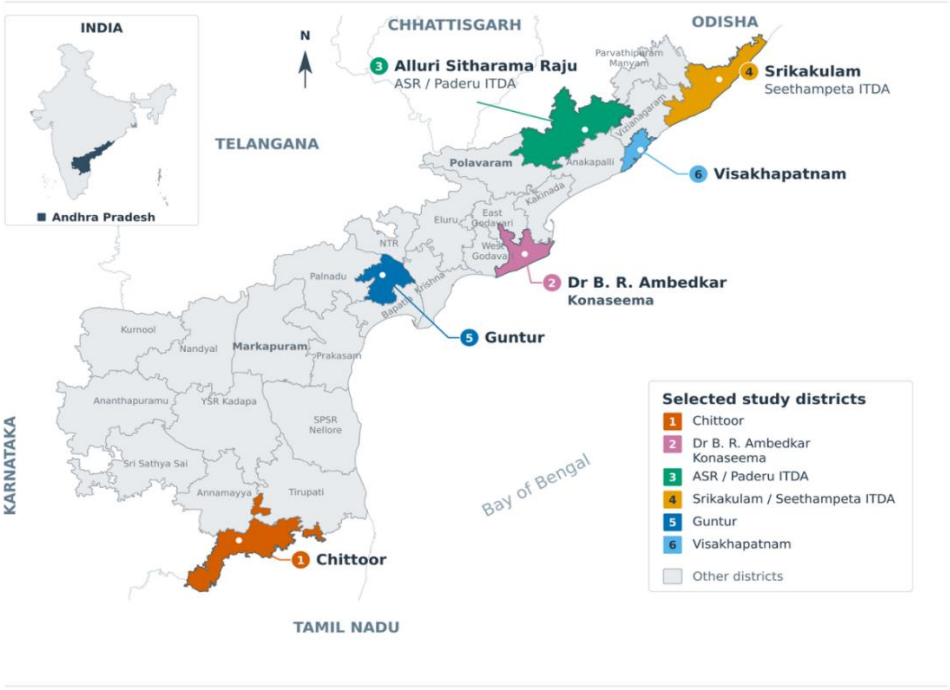


Figure 1. Study Districts/Areas in Andhra Pradesh, India

Participants and Sampling

A purposive stratified sampling strategy was employed to ensure representation across healthcare-provider cadres and geographic settings. Six districts were purposively selected to capture variation in urban, rural, and tribal healthcare contexts. Within each district, six healthcare providers were recruited, comprising two ANMs, two CHOs/MLHPs, and two MOs. Thus, the final sample consisted of 36 healthcare providers, with 12 participants from each cadre.

Eligibility Criteria

Participants were eligible if they (i) were ANMs, CHOs/MLHPs, or MOs working in the selected study districts; (ii) had direct experience using or engaging with digital health applications relevant to maternal, infant, reproductive, child, or primary healthcare services, including associated reporting and

monitoring functions; (iii) had preferably completed at least six months in their current role or had equivalent experience with the relevant digital health application; and (iv) were willing and able to provide informed consent. Direct experience with AI-enabled functions was not required for participation, as the study also explored providers' awareness, exposure and perceptions of AI alongside their routine use of digital health applications. Healthcare providers who had no direct involvement with the relevant digital health applications or associated maternal and child healthcare functions were excluded.

Data Collection

Data were collected through individual semi-structured interviews with health care providers. The interview guide was developed as part of the doctoral research programme; eight predefined themes were developed from the study objectives, research questions, and from the existing literature for the mixed methodology doctoral research proposal. The interview guide comprised of these eight predefined themes for data collection, which were rephrased after pilot to meet the qualitative study requirements.

1. Perceived contributions of digital health interventions to maternal and infant health outcomes.
2. AI-enabled risk assessment and clinical decision support.
3. Enhancement of healthcare providers' knowledge and skills.
4. Implementation, integration, and scalability of digital health technologies in India.
5. Ethical, confidentiality, and privacy concerns associated with AI integration.
6. Algorithmic bias and potential health disparities.
7. Risks associated with over-reliance on AI-enabled tools.
8. Equity and access in digital health.

These 8 predefined themes formed the initial deductive framework, while additional codes were added inductively when relevant concepts emerged from the interview data. The interviews explored participants' experiences of using digital health and AI-enabled applications, perceived benefits, challenges encountered during routine use, and factors influencing implementation and potential scale-up. The semi-structured format allowed the interviewer to use probes and follow-up questions to clarify participants' experiences and explore issues that emerged during the interviews.

Interviews were conducted remotely using Microsoft Teams. Participants were offered the choice of Telugu, English, or a combination of both languages, according to their preference and the language used in their professional communication. Each interview began with the collection of relevant demographic and professional information, followed by discussion of the study themes. With participants' informed consent, interviews were audio-recorded. The recordings were transcribed verbatim. Interviews conducted wholly or partly in Telugu were translated into English for analysis, with attention to preserving the contextual meaning, participants' intended interpretations, and commonly used clinical and digital-health terminology. Transcripts were reviewed against the recordings to ensure accuracy before analysis.

Transcript Preparation and Verification

Transcripts were reviewed against the available source material before coding. Where bilingual transcripts were used, Telugu text was retained alongside the English translation to allow verification of meaning. Potential transcription errors, unclear words, inconsistent numbers, or ambiguous technical terminology were reviewed and verified against the corresponding recording and transcript text.

Qualitative Data Analysis

The interview data were analysed using qualitative content analysis with a hybrid deductive–inductive coding approach, informed by [20]. Qualitative data analysis workflow process was shown in the Figure 2. Using Excel and Word to Structure Qualitative Data. The eight predefined areas of inquiry formed the initial deductive framework, while additional codes were developed inductively from emerging concepts.

Following transcription, interviews were organised in Word and transferred to Excel for systematic coding, sorting, and comparison. Coding was conducted at the level of meaning units, with multiple codes applied where appropriate. The coding structure was reviewed and refined iteratively, including revisiting earlier transcripts to maintain consistency. The primary coding was conducted by the first author. The coding framework and selected coded excerpts were reviewed by the co-authors, and any differences in interpretation were discussed and resolved by consensus. Coded data were consolidated and organised into broader categories and subcategories, while respondent identifiers were retained for traceability. The final analysis examined patterns and variations across healthcare-provider cadres, districts, sampling strata, and facility settings, with findings mapped to the predefined areas and emergent categories.

The final findings were mapped back to the eight thematic areas predefined in the doctoral research proposal. However, based on the results, the thematic areas have been rephrased while keeping the context intact corresponding to the eight themes. For reporting, closely related findings under T6 (AI bias and health disparities) and T8 (equity and access in digital health) were presented together in a single Result to avoid artificial separation of overlapping evidence; all eight predefined thematic areas remained represented in the analysis.



Figure 2. Qualitative Data Analysis Workflow

Analytic rigour

To strengthen analytic credibility and transparency, a versioned codebook and change log were maintained throughout the coding process. Coding decisions were compared across interviews to ensure that code definitions were applied consistently. Representative and analytically important passages were reviewed against the corresponding transcript text, and publication quotations were checked before inclusion in the Results section.

Statements describing improved outcomes were treated as provider-reported perceptions rather than descriptive measured values. Negative and contrasting statements were retained to avoid presenting only dominant views. Sampling stratum and actual facility setting were maintained as separate analytic variables to prevent misclassification of participants. No inferential statistical analysis was performed for the qualitative component. Descriptive counts may be used to summarize participant characteristics or the distribution of coded material where relevant; however, code frequencies were interpreted only as descriptive indicators and not as prevalence estimates or measures of statistical association.

Ethical Considerations

Initial permission was sought from the Andhra Pradesh State Health Department to conduct the interviews followed by individual consent. Participation was voluntary, and informed consent was obtained before each interview. Participants were informed about the purpose of the study, the use of audio recording, confidentiality of their responses, and their right to decline or discontinue participation. Personal identifiers were excluded from the analytic dataset and published quotations. Interview IDs were used during coding and reporting. Audio recordings and transcripts were stored securely, and information was used only for the approved research purpose.

Results

Across the 36 interviews, healthcare providers reported extensive use of digital health applications for registration, follow-up, high-risk identification, programme monitoring, teleconsultation, reporting and service documentation. However, explicit use of artificial intelligence (AI) was considerably less common than routine digital health use. The perceived benefits of digital systems centred on continuity of information, identification and monitoring of high-risk cases, reminders, referral support and programme visibility. At the same time, providers reported persistent challenges related to network connectivity, fragmented applications, repeated data entry, authentication requirements and reduced time for direct beneficiary interaction. Across cadres, professional judgement remained central to clinical decision-making, even where digital prompts or AI-enabled functions were available.

Based on the qualitative content analysis seven interrelated categories were generated : (1) digital continuity, follow-up and access to care; (2) risk identification and clinical decision support; (3) provider knowledge, training and technical support; (4) implementation, interoperability and workflow burden; (5) privacy, authentication and trust; (6) bias, equity and last-mile access; and (7) AI use, professional autonomy and over-reliance. All eight predefined themes remained represented in the analysis; however, Theme 6 (AI bias and health disparities) and Theme 8 (equity and access in digital health) showed substantial overlap in the interview data. These two themes were therefore combined for reporting, resulting in seven reported categories.

Digital Continuity, Follow-up and Access to Care

Digital applications supported several aspects of maternal and child healthcare, including beneficiary registration, reminders,

follow-up and retrieval of previous information. The nature of use differed across professional cadres. ANMs and CHOs/MLHPs more frequently described operational functions such as reminders, vaccination tracking and follow-up of high-risk beneficiaries, whereas Medical Officers (MOs) more often emphasized programme visibility, retrieval of clinical information and access to specialist consultation.

Digital reminders were particularly useful for identifying pending antenatal services, immunization doses and high-risk follow-up. Providers described these alerts as supporting continuity in settings where high workloads could otherwise result in missed follow-up. One ANM explained:

> *"With a heavy workload, cases can sometimes be forgotten; the high-risk reminder helps us remember the mother, birth planning and transport planning. In the RCH portal we can see ANC service due dates, child vaccination dues and pending third or fourth check-ups. These alerts help us remain attentive."*

Digital records could also facilitate re-engagement with beneficiaries who moved between locations. However, continuity often weakened after referral because subsequent treatment information was not consistently visible to the referring provider. This limitation was reported by both frontline providers and Medical Officers. In one account, an MLHP described how a woman who had migrated during pregnancy subsequently reappeared in the application, allowing the healthcare team to trace her location, reassess her condition and initiate referral:

> *"One pregnant woman was anaemic when she registered. She later migrated and we could not contact her or identify where she was staying. In the ninth month she appeared again in the application. We traced her location, visited her home, identified very low haemoglobin and pedal oedema, and she was referred for further treatment."*

Teleconsultation was reported primarily by CHOs/MLHPs and Medical Officers. It was perceived as improving access to doctors and specialists, particularly where specialist services were not locally available. However, its usefulness was constrained by connectivity problems and the availability of the specialists.

These benefits were not uniform across participants, as continuity was limited when post-referral information was not visible to the referring provider and when connectivity constrained teleconsultation. Providers noted that information generated after referral was not consistently visible to the referring provider, limiting the potential for fully integrated continuity of care.

Risk Identification and Clinical Decision Support

Identification and monitoring of high-risk pregnancies was one of the most consistently reported digital functions across cadres and geographic settings. ANMs particularly emphasized pregnancy risk flags, haemoglobin monitoring and reminders for due-services, whereas CHOs/MLHPs and MOs more often discussed referral decisions, interpretation of digital information and the limitation of automated support.

Colour-coded displays were described as a practical mechanism for distinguishing routine from high risk cases. One ANM explained:

> *"It is normal. It comes in blue colour. Anything that is high risk will come in red colour."*

Providers linked these digital risk indicators to follow-up, referral, admission planning and treatment. Anaemia was frequently mentioned, particularly in relation to recording and monitoring haemoglobin values. However, respondents distinguished between systems that flagged or displayed risk information and systems that independently generated a clinical diagnosis or decision.

"At present there is no application that identifies a condition based on symptoms. We identify the symptoms ourselves and immediately refer the patient to the Medical Officer."

Much of what participants described as "digital" or "automated" support consisted of structured alerts, colour-coded risk indicators, reminders and prompts rather than verified AI-based clinical reasoning. Accordingly, these functions are more appropriately characterized as digital risk identification and clinical decision support, unless participants explicitly identified an AI-enabled function. This distinction was consistent across cadres, with participants describing digital prompts as supportive to clinical decision-making rather than as independent diagnostic tools.

Provider Knowledge, Training and Technical Support

Provider capacity to use digital systems was shaped by the availability and form of training and technical support. Providers described formal training sessions, Zoom based sessions, peer learning, instructional videos, in application educational material and district-level technical assistance. CHO/MLHP particularly reported using educational content within applications, including materials related to Ante Natal Care (ANC), Post Natal Care (PNC), infant care and other health topics. These resources were sometimes used both provider learning and beneficiary counselling.

"The CHO Application contains videos on ANC care, PNC care, infant care and NCD related topics. We can review them when we have doubts, and we also show the videos to patients."

Training pathways nevertheless varied across cadres. Several ANMs described learning primarily through colleagues or videos shared outside the formal application rather than through structured application-based training. Whereas MOs frequently referred to formal orientation associated with newer systems or pilots. Technical support from district teams provided an additional mechanism for resolving application-related problems. Training experiences therefore varied by cadre, with no single standardized learning pathway reported across participants.

Overall, implementation depends on a combination of formal training, peer learning, application-based resources and external technical assistance rather than on a consistently standardized training model.

Implementation, Interoperability and Workflow Burden

Although digital systems improved programme visibility and documentation, their implementation also generated substantial workflow challenges. The most frequently reported barriers were poor network connectivity, server or application failure, fragmented platforms, repeated data entry and increased workload. Connectivity problems were reported across settings but were particularly prominent in tribal-selected districts where poor or absent network coverage was described as a structural constraint. Fragmentation between applications was especially evident in rural-selected interviews.

Providers reported entering the same beneficiary information into multiple platforms, including Reproductive and Child Health (RCH), ANM Online (ANMOL), Universal Immunization Programme WIN (U-WIN) and other applications. Repeated data entry increased workload and reduced the time available for direct interaction with beneficiaries. This increased workload and reduced beneficiary interaction time. One provider summarized this burden:

"There are too many apps at field level. The same data have to be entered in RCH, ANMOL and U-WIN, and ABHA-related processes may also be repeated. It would be better to reduce duplication."

The consequences differed by professional role. ANMs and CHOs/MLHPs more often

described the effects on field work, counselling and direct beneficiary interaction, while MOs emphasized reporting, monitoring, programme performance. An ANM noted:

> *"The challenge is that there is a lot of online work now. Because of that, we have very little time to go into the field and do offline, field-level work."*

At the same time, Medical Officers frequently valued improved programme visibility, dashboards and monitoring. This finding illustrates an important implementation tension: the same systems that enhanced programme-level visibility and monitoring could simultaneously increase documentation demands at the frontline. The operational burden was therefore more visible among ANMs and CHOs/MLHPs, while Medical Officers more often emphasized programme monitoring and reporting benefits.

Privacy, Authentication and Trust

Providers generally perceived digital health information as secure, when access was restricted through authorized logins. However, their understanding of data storage and or broader data governance was limited. In practice, authentication requirements were a more immediate concern than abstract data security issues. One Time Password (OTP) requirements, Aadhaar linked mobile numbers and biometric authentication were described as recurring barriers, particularly for beneficiaries with limited literacy, limited access to mobile phones or difficulty using authentication systems. One provider explained:

> *"Making OTP mandatory causes significant difficulty. Many patients are elderly or have limited literacy; some do not have a phone or do not know how to provide an OTP."*

Providers also described situations in which beneficiaries were reluctant to share OTPs because mobile phones themselves warned users against disclosing them. Shared family phones and unavailable Aadhaar linked numbers created additional difficulties.

Confidentiality concerns were discussed most explicitly by MOs, particularly in relation to sensitive health information. Providers emphasized that maintaining beneficiary trust was viewed as a professional responsibility irrespective of whether information was stored digitally or in paper records. Across cadres, practical authentication challenges were discussed more often.

Bias, Equity and Last-Mile Access

Direct evidence concerning algorithmic bias was limited. A small number of providers reported that they had not observed different clinical suggestions according to socioeconomic status, gender or rural urban residence. These accounts represent provider perceptions and should not be interpreted as evidence that algorithmic bias is absent.

One CHO described application questions as being influenced by clinically relevant information such as sex or entered risk factors but not by rural or urban residence. This suggests that providers perceived some differentiation as clinically driven rather than discriminatory.

A more consistently reported equity concern was unequal ability to access and use digital services. CHOs and MOs described beneficiaries who didn't have personal mobile phones, shared telephone numbers across family members or experienced difficulties with OTP-based authentication. In tribal settings, these barriers were compounded by poor connectivity and transport difficulties.

> *"Sometimes, all seven or eight members of a family are linked to the same phone number."*

The finding therefore suggest that digital identification of risk doesn't necessarily translated into timely access to care. In remote settings, distance, transport availability, network connectivity and authentication barriers could still delay referral and follow-up. At the same time, digital records occasionally

enabled providers to reconnect with beneficiaries who moved between locations.

Thus, the principal equity concerns emerging from the interviews related less to differential algorithmic recommendations and more to unequal capacity to access, authenticate and act upon digitally mediated healthcare services. Overall, participants described equity concerns more often in relation to access and authentication barriers.

AI Use, Professional Autonomy and Over-Reliance

Explicit AI use was limited and uneven, while most participants primarily described routine digital health functions rather than confirmed AI-enabled features. Participants described AI-related functions involving information seeking, voice-assisted documentation, administrative data extraction and advisory supports. MOs reported greater direct exposure to AI-enabled functions, including diagnostic suggestions and voice-assisted documentation. Some ANMs reported using AI-supported information or explanation functions, whereas several CHOs/MLHPs reported limited familiarity with AI.

Where AI generated diagnostic or advisory outputs were encountered, MOs emphasized the need for professional verification.

> *"The application can generate a diagnosis, but sometimes it is not appropriate. In that situation, I have to correct it and enter the information manually. Clinical judgment is still necessary."*
>
> *"AI still needs to improve further in the medical field. Without the human touch and clinical judgment of a physician, it can be difficult to arrive at an accurate diagnosis, even if all the symptoms are provided."*

These accounts indicate that participants generally viewed AI as supportive rather than substitutive. Professional autonomy was retained at the level of clinical judgement, although providers remained operationally dependent on digital systems for registration, reporting and documentation. This distinction between clinical autonomy and digital-system dependence was evident across the interviews. Across cadres, AI was generally viewed as supportive rather than substitutive, with clinical judgement retained by healthcare providers.

Together, the findings indicate that digital health has become embedded in routine maternal and child healthcare delivery, particularly for registration, follow-up, risk identification, monitoring and reporting. However, implementation benefits were accompanied by interoperability problems, documentation burden and access barriers. Explicit AI use remained comparatively limited and was characterized primarily as an assistive technology requiring human verification. The central finding across the themes was therefore not technological replacement of healthcare providers, but an evolving relationship in which digital systems increasingly mediate healthcare work while clinical responsibility remains with frontline professionals.

Discussion

This study found that digital health applications were increasingly embedded in routine maternal and infant healthcare, particularly for documentation, monitoring, high-risk identification, follow-up, and continuity of care. However, Direct exposure to AI-enabled functions remained limited and uneven across healthcare cadres. Providers generally viewed digital and AI-enabled tools as supportive mechanisms rather than replacements for professional judgement, with clinical decision-making remaining under healthcare-provider oversight.

The findings also highlight important technical, organisational, workforce and equity-related barriers to digital health integration. Although providers valued improved access to information, teleconsultation, reminders and monitoring, implementation was constrained by poor

connectivity, device limitations, fragmented applications, repeated data entry, authentication requirements, technical problems and inadequate training [21]. Similar implementation challenges have been reported in the TECHO+ programme in Gujarat, where frontline health workers described connectivity and software problems, training limitations, adaptation to digital technologies, and additional workload from maintaining parallel digital and paper records [22]. Recent evidence from India similarly identifies difficulty using digital health applications, privacy concerns, language barriers and hesitation to share OTPs as important barriers to ABDM use [23]. These challenges contributed to increased workload and disruption of routine workflows.

Geographical and cadre-specific differences were also evident. Connectivity and physical access barriers were more prominent in tribal-selected settings, while duplicate data entry and workflow burden were particularly evident in rural-selected interviews. ANMs primarily highlighted field-level follow-up and workload; CHOs/MLHPs emphasised teleconsultation and counselling support; while Medical Officers more frequently discussed programme monitoring, privacy, AI functionality and professional oversight. These cadre-specific differences are consistent with evidence that frontline rural health workers' readiness for mobile-phone-based telemedicine varies across knowledge, attitudes and practice domains [24].

Overall, the findings suggest that effective use of digital health applications and AI-enabled functions also depends on infrastructure, interoperability, training, technical support, and healthcare provider oversight [7]. Reliable infrastructure, interoperable and user-friendly platforms, adequate training, technical support and continued professional oversight are essential. Particular attention is needed in rural and tribal settings, where digital exclusion may intersect with geographical, infrastructural and access-related inequalities. A context-sensitive, provider-centred and equity-oriented approach may therefore be critical for ensuring that digital innovation strengthens rather than adds to the burden of maternal and infant healthcare delivery.

Conclusion

This study shows that digital health applications are integrated into several aspects of routine maternal and infant healthcare in Andhra Pradesh, particularly for documentation, follow-up, monitoring, teleconsultation and continuity of care, with limited explicit AI use. Healthcare providers generally viewed digital health applications and AI-enabled functions as supportive tools, with clinical decision-making remaining under provider judgement. Their effective use was influenced by both enabling and constraining factors, including infrastructure, connectivity, interoperability, device availability, training, technical support, workflow integration, authentication requirements, privacy considerations and local service-delivery conditions. Differences across urban, rural and tribal settings further indicate that implementation cannot be approached uniformly. The study extends existing evidence by providing provider-level insights into how AI and digital health applications are experienced within routine maternal and infant healthcare and by highlighting the distinction between widespread digital application use and more limited AI-enabled functionality. These findings suggest that future implementation should consider interoperability, reliable infrastructure, technical support, appropriate training, privacy safeguards, and continued healthcare-provider oversight, particularly in rural, tribal, and other resource-constrained settings.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Author Contributions

Pavani Divi: Conceptualization, literature search, developed semi-structured interview tool, conducted qualitative interviews, data extraction, thematic synthesis, original draft preparation, and review. Aparajita Mishra & Pragath Kumar Ponnam: Review and editing, methodological guidance, critical revision of intellectual content and contextual validation of India-specific content. Abiodun Olaiya Paul: Review and editing, methodological guidance and supervisory oversight. K V N S Anil Kumar: Review, guidance and critical appraisal.

Ethical Approval

Ethical approval for the doctoral research study was obtained from the Institutional Ethics Committee, Dr Patnam Mahender Reddy Institute of Medical Sciences; Approval No. IEC/PMRIMS/0121, dated 22/03/2025. Administrative permission to conduct the study was also obtained from the Maternal and Child Health Department, Office of the Commissioner of Health and Family Welfare, Government of Andhra Pradesh. The study followed the ethical considerations specified by the Texila University for research proposal development, includes informed consent, confidentiality and participant anonymity. Respondents' participation was voluntary, and informed consent was obtained from all participants before the interviews.

Data Availability

The qualitative data supporting the findings of this study are not publicly available because of participant confidentiality. Data with only interview IDs may be made available by the corresponding author upon request.

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Increasing Substance Use as a Cause of Road Transport Crashes in Nigeria: A Review of the Screening Methods

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Abstract *Road transport crashes contribute to significant morbidity and mortality in Nigeria. Psychoactive substance abuse among drivers contribute to the crash. However, screening for substance use among drivers are inconsistent. To determine the available screening methods for identifying psychoactive substance use among drivers in Nigeria, a systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. Four studies were identified and 50% of them met the inclusion criteria. Urine toxicology testing and breathalyzer testing were the main screening methods identified. The toxicology assays can detect many substances while breathalyzers provide rapid roadside detection of alcohol. A unified screening protocol for substance use among drivers in Nigeria is lacking. Developing and implementing a unified comprehensive screening will improve road safety in Nigeria.*

Keywords *Crashes, Nigeria, Road, Screening, Substance Use, Transportation.*

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Introduction

The incidence of road transport crashes in Nigeria continues to add to the increasing global data on morbidity and mortality following trauma. It continues to be a primary cause of death and a significant economic burden globally [1]. Consequently, it is anticipated that without ongoing interventions, road transport crashes will rank as the seventh leading cause of mortality by 2030 [1]. It could worsen the socioeconomic difficulties of various nations of the world, especially the developing nations.

In Nigeria, the road is the most feasible means of transportation for a significant portion of its population. However, there are inherent risks associated with road transportation system in Nigeria. There are poor road maintenance, violent crime, unsafe driving practices, and road crashes associated with the road transportation system. The Federal Road Safety Corps (FRSC) reported that in 2024, there were 5,421 fatalities resulting from 9,570 recorded road accidents [2]. Studies have consistently demonstrated the link between human factors, such as speeding, fatigue, substance abuse, and road accidents [3]. A study conducted in 2023 estimated that around 14.4% of Nigerians between the ages of 15 and 64 partake in the use of psychoactive substances [4]. Within the group of commercial drivers, the consumption of stimulants, cannabis, alcohol, and various combinations of these substances is prevalent, especially as a means to cope with the tiring long-distance of the journey. Driving under the influence of illicit substances adversely impacts mental capacity, instinct, discernment, and awareness [5]. Therefore, substance abuse is a significant factor in the increasing rate of road transport crashes in Nigeria.

In Nigeria, screening techniques for substance use among drivers involved in road transport crashes include roadside inspections and medical toxicology assessments conducted after crashes [6]. The Federal Road Safety Corps (FRSC) occasionally employs Breathalyzer Tests for immediate roadside alcohol detection to assess blood alcohol concentration in drivers. Nigeria's numerous fatal road crashes have been linked to alcohol, but toxicology drug tests are rarely done at crash sites; offenders are largely not held accountable. The legislation regarding Blood Alcohol Concentration (BAC) in Nigeria is weak or non-existence [7].

The National Drug Law Enforcement Agency (NDLEA) employs Rapid Immunoassay Urine assay during occasional motor-park outreaches and joint operations to screen for cannabis, tramadol, codeine, and amphetamines among drivers. These screening methods are not routinely carried out. They are often employed during the "ember months" when the incidence of road transport crashes is relatively higher [2].

The rising prevalence of psychoactive substances is a significant and potentially avoidable factor contributing to road transport crashes in Nigeria [8, 9]. Therefore, the effective identification of substance use among drivers is crucial for enhancing road safety, facilitating early intervention, and bolstering enforcement and public health initiatives. This review explores the various methods available for screening substance use in drivers, which include biological testing, roadside screening, and other innovative approaches. Self-report using questionnaire has been well documented. By assessing the strengths, weaknesses, feasibility, and relevance of these methods within the Nigerian context, the review seeks to pinpoint practical strategies that can enhance the detection of substance-impaired driving, ultimately aiding in the prevention of road transport crashes and the associated injuries and fatalities.

Methods

We performed a systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)

guidelines 2020 [10]. The review process involved screening to identify, assess, and synthesize data concerning the screening practices for psychoactive substance use among drivers in Nigeria. An initial search was performed to locate studies. Following this, a screening process was undertaken to ensure that studies included in the review met the inclusion and exclusion criteria. Data were extracted and synthesized from the reviewed articles.

Studies were considered for inclusion if they: (a) were carried out in Nigeria; (b) involved drivers or other road users; (c) reported the implementation of one or more screening techniques for identifying substance abuse; and/or (d) investigated the relationship between illicit substance use and road traffic accidents.

Eligible studies encompassed cross-sectional and various observational studies that offered pertinent information regarding the methods employed to screen for illicit substance use among drivers or individuals involved in road transport crashes. Studies that provided adequate details on the type, procedure, or application of screening methods were given priority for analysis.

We conducted a systematic search of the literature using the search terms “road transport crashes and substance abuse screening among drivers in Nigeria,” and “road transport accidents and screen for illicit substance use among drivers in Nigeria,” in PubMed, Google scholar, Bielefeld Academic Search Engine, and CORE. No language or publication date restrictions were applied.

Results

We identified 4 studies through database searching. After review, we selected 2 studies after applying the inclusion criteria. A urine toxicology assay using a test kit for the presence of ten psychoactive drugs: cocaine, oxycodone, morphine, amphetamine, methamphetamine, methadone, barbiturates, cannabis, benzodiazepines, and phencyclidine is popular among researchers. The breathalyzer is mostly used by the Federal Road Safety Corps.

Table 1. Articles on Screening Methods for Psychotropic Substances Among Drivers in Nigeria

Authors	Screening Method	Participants Enrolled	Methodology	Prior Crash Involvement (%)	Findings
Egwuatu et al 2020 [11]	Urine Toxicology	264	Cross Sectional Study	46	Different psychoactive substances in the urine. Cannabis is the commonest (29.2%)
Iwegbu et al 2025 [15]	Urine Toxicology	1200	Cross Sectional Study	-	Different psychoactive substances in the urine. Alcohol is the commonest (16.0%)

Discussion

This review evaluated the screening techniques employed to identify substance use among drivers and individuals involved in road transport crashes in Nigeria. Out of the four studies found through database searches, only two satisfied the established inclusion criteria. The limited number of qualifying studies underscores the scarcity of research specifically focused on the screening of illicit and psychoactive substance use among drivers in Nigeria. This observation may indicate that, despite rising concerns regarding substance use and its possible role in road transport crashes, systematic screening and research in this domain are still inadequate.

This review's findings reveal that urine toxicology testing is frequently utilized for identifying psychoactive and illegal substances in drivers and other road users within research contexts [11]. The toxicology tests identified are capable of screening for a variety of substances, such as cocaine, oxycodone, morphine, amphetamine, methamphetamine, methadone, barbiturates, cannabis, benzodiazepines, and phencyclidine. The capacity to detect multiple substances at once is a significant benefit of urine toxicology screening, especially in environments where polysubstance use may be prevalent. This type of screening can yield valuable evidence of recent exposure to psychoactive substances and may aid researchers in assessing the extent of substance use among drivers.

Nevertheless, the application of urine toxicology testing carries significant limitations. A positive urine test does not necessarily imply that a driver was impaired at the precise moment of driving or during the occurrence of a road traffic accident [12]. The detection window for numerous substances can extend beyond the period of acute intoxication, influenced by the type of substance, frequency of use, dosage, and individual metabolic characteristics [13]. Consequently, while urine toxicology tests are valuable for detecting substance exposure, one must exercise caution when interpreting positive results as definitive proof that substance use led to a specific road traffic accident. Whenever feasible, toxicological results should be analyzed in conjunction with clinical evaluations, driving behavior information, crash circumstances, and other pertinent factors [14].

The fact that cannabis was the most frequently abused psychoactive substance among the assessed drivers as shown in Table 1 on the first reviewed article, is a worrying discovery. This is because cannabis may have adverse effects on a driver's ability and may increase the likelihood of causing or being involved in a road traffic crash. Cannabis impairs attention and concentration, reaction time and speed, judgment and coordination, and the ability to take timely action in response to roadway hazards [15]. In addition, a study conducted in Nigeria established that cannabis use among commercial drivers was significantly associated with an increased risk of road traffic crashes, especially when combined with alcohol consumption [6]. A study of long-distance commercial drivers in Nigeria also established that cannabis-related driving impairment and concurrent alcohol use were significantly associated with increased odds of crash involvement [16].

Ingestion of the substance may increase drivers' sense of well-being and alertness; therefore, the drivers may not realize the extent of their impairment by cannabis and continue to drive instead of pulling over to seek assistance. Cannabis may also be taken in combination with other substances which may complicate toxicological screening and make it hard to identify the cause of a crash, particularly if multiple drugs are involved. As such, the detection of cannabis as the commonest substance of abuse among drivers is a critical issue and a call for enhanced screening practices to include other psychoactive substances alongside alcohol. Drivers should be educated about the risks associated with operating a motor vehicle under the influence of any substance. Selected programs should also be prioritized and implemented to promote awareness and reduce substance abuse among drivers in Nigeria.

Alcohol abuse is another serious public health problem in Nigeria due to the high prevalence in the population. In fact, there are reports that drivers are among the groups of people who abuse drugs and take them regularly. However, there are contradiction with the findings of the study by Egwuatu et al, which identified cannabis as the most commonly abused substance [11]. Other studies among commercial drivers have reported alcohol as the predominant substance of use. In

Umuahia, southeastern Nigeria, Akande et al. found that alcohol was the most commonly used substance among commercial bus drivers, reported by 51% of participants, compared with 8.5% for cannabis [6]. Similarly, a study of long-distance commercial drivers in Calabar reported alcohol use among 82% of respondents, making it the most frequently used psychoactive substance [17]. These differences might be explained by variations in geographical setting, occupational characteristics, cultural norms, substance availability, and study methodology. Alcohol is legal, relatively accessible, and socially accepted in many communities, which may contribute to more frequent use and greater willingness to disclose consumption. In contrast, cannabis use might be underreported due to its illegal status, stigma, or fear of legal consequences. Furthermore, differences in screening methods influence the findings, as questionnaire-based studies might capture lifetime or recent use, while toxicological testing identifies substances present within a specific detection window. However, the identification of alcohol as the commonest substance in other studies supports the need of road-safety screening protocols in Nigeria to assess both alcohol and illicit substances rather than focusing on cannabis alone.

The review indicated that the breathalyzer is primarily utilized by the Federal Road Safety Corps for conducting roadside screenings on an occasional basis [2]. This device offers a relatively swift and effective means of evaluating alcohol consumption among drivers, making it particularly advantageous for regular roadside enforcement [18, 19]. In contrast to laboratory-based toxicological assessments, breath alcohol testing delivers immediate results, thereby facilitating timely enforcement of regulations concerning driving under the influence of alcohol. Nonetheless, the evident dependence on breathalyzer testing may suggest a deficiency in the routine roadside screening for other psychoactive substances. Although alcohol significantly contributes to impaired driving, it is important to note that drivers may also consume cannabis, opioids, stimulants, benzodiazepines, and various other psychoactive substances that a standard breathalyzer cannot detect [20].

The results indicate a potential gap between research-oriented and enforcement-oriented screening methods in Nigeria. It seems that researchers predominantly utilize urine toxicology tests that can identify a broad spectrum of illegal and psychoactive drugs, while standard enforcement practices tend to concentrate on alcohol detection via breathalyzer tests. This discrepancy could hinder the recognition of drug-impaired driving and may lead to an underappreciation of the role that illegal and other psychoactive substances play in road traffic accidents.

Psychoactive substances are becoming readily accessible in Nigeria [21, 22]. Therefore, consumption is becoming a daily event among drivers in Nigeria. It is therefore imperative to screen drivers for the use of these substances. Roadside screening aids in rapid identification of culpable drivers who need additional toxicological evaluation, while laboratory confirmatory assays make certain the substance identification. In addition, well-structured screening protocols would enhance the comparability of results across various parts of Nigeria.

The identification of only two studies that met the criteria in the index review highlights a significant research gap on screening methods employed in Nigeria or substance abuse among drivers. This shows that most studies in Nigeria about substance abuse by drivers rely on self-report by the drivers, which is highly subjective [23, 24]. The attendant implication is that it is difficult to give the actual prevalence of drivers under the influence of substance abuse in Nigeria. Hence, there is an urgent need for a comprehensive screening method among the drivers. Future research must include a wide number of substances, including those not

detectable by urine, like synthetic cocaine (K2), standardized screening methods, suitable biological testing, and elaborate data about various crashes in different parts of Nigeria. The outcomes of such research should assist the policy makers in addressing the increasing rate of road crashes in Nigeria.

The limited literature on substance-impaired driving in Nigeria, as well as the absence of routine screening for drugs other than alcohol, compromises road safety in the country. While alcohol is indeed a significant contributor to road traffic crashes, the fact that other psychoactive substances including stimulants, cannabis, opioids, and prescription medicines are increasingly being used by drivers requires more attention. The reliance on alcohol screenings only may compromise efforts to reduce road traffic injuries by underestimating the role of other substances in traffic crashes in Nigeria [25]. In addition, the lack of uniform screening practices makes it difficult to assess the extent of the problem based on positive results from toxicological screening [26].

Facilitating collaboration across healthcare, law enforcement, and road safety agencies in Nigeria to develop a consensus on the principles of standardized toxicological screening for drivers is critical to addressing the challenge of substance-impaired driving. The protocol should be guided by considerations such as the type of specimen, screening and confirmatory tests, and standard operating procedures for collecting and analyzing samples, reporting results, and interpreting findings. Conducting more studies on substance-impaired driving in different regions and among various categories of road users in Nigeria will also contribute to a better understanding of the issue. For example, more data on the relationship between the type of psychoactive substance, occupation, age, location, and severity of traffic crashes would help the Federal Road Safety Corps (FRSC) and other relevant agencies to develop effective countermeasures.

Such measures will ultimately improve road safety in Nigeria by providing the FRSC, law enforcement agencies, and other stakeholders with critical information needed to promote safer driving, prevent traffic crashes, and determine the appropriate toxicological screening for drivers in Nigeria. In addition, cooperation among the FRSC, law enforcement agencies, healthcare facilities, and researchers in Nigeria can generate the necessary evidence to guide the development of countermeasures that reduce road traffic injuries and deaths attributable to substance-impaired driving.

Conclusion

The review identified the lack of epidemiological research on screening methods for the use of psychoactive substances among drivers in Nigeria. Toxicological screening of urine is useful, but other methods should be expanded for suspected drivers under the influence of psychoactive substances. Although a breathalyzer test is a rapid screening tool for alcohol, it does not detect other psychoactive substances. Further studies on the prevalence of substance use among drivers and improved screening procedures during traffic checks are needed to enhance the current understanding and reduce substance use among drivers in Nigeria. Standardized and comprehensive toxicological screening protocols should be developed and implemented across relevant road safety and healthcare settings. Law-enforcement and healthcare personnel should be trained in the recognition of substance-related impairment and the use of reliable screening tools. Access to confirmatory laboratory testing would improve the reliability of screening results and legal and clinical decision-making.

Collaboration among road safety agencies, healthcare institutions, toxicology laboratories, and researchers is also needed for effective surveillance. Public education campaigns targeting commercial and private drivers should target the risks associated with driving under

the influence of psychoactive substances. These steps would strengthen evidence-based road safety interventions and reduce substance-related road traffic crashes, injuries, and deaths in Nigeria.

Establishing a national database for substance-related traffic incidents would improve surveillance and interventions. Evaluation of screening practices and road safety policies will be needed to ensure that interventions respond to emerging patterns of psychoactive substance use among Nigerian drivers.

Conflict of Interest

The authors affirm that they do not have any financial affiliations presently or within the preceding three years with any organizations that could potentially influence the submitted work. They further assert that no other associations or engagements might give rise to perceived influences on the submitted work. The authors confirm the absence of any conflicts of interest. All authors provide their consent for the publication of this manuscript.

Ethical Approval

This is a systematic review; ethical approval is not needed.

Authors' Contributions

All authors contributed to the project's conception and design, as well as the development of the project. All authors participated in the literature review, data analysis, and manuscript preparation. All authors approve the final version of the manuscript for submission.

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Data Availability

The data set related to this study were from the two papers that met the inclusion criteria.

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Child Food Poverty among Children Aged 6–23 Months in the Maradi Region, Niger: A Cross-Sectional Study of Magnitude, Associated Factors, and Urban–rural Disparities

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Abstract *Child food poverty, defined by the UNICEF framework according to the number of food groups consumed in the previous 24 hours, is an indicator of inadequate dietary diversity among young children. This study assessed the prevalence of child food poverty, its associated factors, and urban-rural disparities among children aged 6-23 months in the Maradi region of Niger. A cross-sectional survey conducted from September to October 2025 included 1,343 children with complete dietary information. Child food poverty was categorized as no food poverty (≥5 food groups), moderate food poverty (3-4 food groups), or severe food poverty (0-2 food groups). Associations were examined using chi-square tests and multinomial logistic regression, while urban-rural differences were assessed using a Blinder-Oaxaca decomposition. Overall, 95.0% of children experienced moderate or severe food poverty, including 51.4% with severe food poverty. Severe food poverty was most common among children aged 6-11 months (90.3%). Rural residence was strongly associated with both moderate (aRRR = 7.20; 95% CI: 3.50–14.82) and severe food poverty (aRRR = 14.69; 95% CI: 6.77–31.87). Children aged 18-23 months were less likely to experience severe food poverty than younger children. Although food poverty was substantially higher in rural areas than in urban areas, observed characteristics did not significantly explain this disparity. These findings underscore the urgent need for interventions targeting dietary diversity, particularly among younger children and rural populations.*

Keywords *Child Food Poverty, Dietary Diversity, Infant and Young Child Feeding, Maradi, Niger, Rural Population, Urban–Rural Disparities.*

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Introduction

The period from 6 to 23 months is a critical window for child growth, development, and the establishment of dietary patterns [1-3]. During this period, children progressively transition from predominantly breast milk-based feeding to complementary foods, while their nutritional requirements increase substantially. The adequacy, quality, and diversity of complementary foods are therefore essential to meeting nutritional needs and supporting healthy growth and development. Inadequate dietary practices during this period may contribute to poor diet quality and increase children's vulnerability to malnutrition and micronutrient deficiencies.

Child malnutrition remains a major public health challenge in low- and middle-income countries, particularly in sub-Saharan Africa [3-6]. Nutritional vulnerability during early childhood is influenced by multiple and interconnected factors, including household socioeconomic conditions, food insecurity, maternal and child characteristics, feeding and caregiving practices, and environmental conditions.

Dietary diversity is an important dimension of this vulnerability because a monotonous diet may limit children's access to a broad range of essential nutrients [1, 2, 7, 8]. Consequently, assessing the quality and diversity of foods consumed by young children is an important component of understanding nutritional deprivation during the complementary-feeding period [4, 7-9].

Historically, the assessment of dietary diversity among children aged 6–23 months has relied extensively on the Minimum Dietary Diversity (MDD) indicator [1]. MDD provides an important measure of whether a child has consumed foods from at least five of the eight recommended food groups during the previous 24 hours, but its binary classification does not distinguish different levels of dietary deprivation. The UNICEF child food poverty framework complements this approach by providing a severity-based classification of dietary deprivation.

Under this framework, children consuming foods from 0–2 of the eight food groups are classified as experiencing severe child food poverty, those consuming 3–4 groups as experiencing moderate child food poverty, and those consuming at least five groups as experiencing no child food poverty [10].

This distinction is particularly relevant from a public health perspective because severe dietary deprivation may identify children experiencing a more profound lack of dietary diversity than can be captured by a binary indicator alone. UNICEF's 2024 global assessment estimated that approximately 181 million children under five years of age were experiencing severe child food poverty, with a particularly high burden in sub-Saharan Africa [5, 10, 11].

Recent studies applying this framework have examined child food poverty in relation to household socioeconomic conditions, maternal characteristics, place of residence, and other contextual factors [8, 9, 12-14]. However, evidence remains limited in many low-resource settings, particularly at subnational level.

Niger continues to face substantial nutritional vulnerability among young children [5, 6, 15]. National nutrition surveillance provides important information on child nutritional status, but such estimates may mask substantial geographic inequalities within regions. The Maradi region is of particular public health importance given the substantial nutritional challenges affecting young children in the region. The broader SMART survey in Maradi was designed to generate geographically disaggregated estimates across the eight departments and the urban municipality of Maradi City.

Previous analyses of the same survey population have reported low attainment of minimum dietary diversity and disparities in infant and young child feeding practices [16].

Nevertheless, the distribution of child food poverty according to its different severity levels, its associated characteristics, and the magnitude of urban–rural disparities remain insufficiently documented at the subregional level in Niger. This evidence gap is important because regional averages may conceal substantial differences between urban and rural populations and between local geographic areas.

A better characterization of child food poverty in this context may therefore contribute to a more precise understanding of dietary deprivation during early childhood and help identify populations requiring greater attention from nutrition programmes.

Examining the urban–rural disparity may also provide complementary information on whether differences in observed child, maternal, household, environmental, and intervention-related characteristics account for the geographic gap in food poverty [9, 13, 14]. The present study therefore aimed to: (i) Estimate the prevalence of moderate and severe child food poverty among children aged 6–23 months in the Maradi region of Niger; (ii) Identify characteristics associated with moderate and severe child food poverty using multinomial logistic regression; and (iii) Examine the urban–rural disparity in child food poverty using a Blinder–Oaxaca decomposition [17, 18].

Methodology

Study Design and Setting

This quantitative cross-sectional descriptive and analytical study was conducted in the Maradi Region of south-central Niger using the SMART (Standardized Monitoring and Assessment of Relief and Transitions) methodology. The region comprises eight departments: Aguié, Bermo, Dakoro, Gazaoua, Guidan-Roumdji, Madarounfa, Mayahi, and Tessaoua; and the urban municipality of Maradi City. Each geographic unit was treated as a distinct survey stratum to permit geographically disaggregated estimates. Data collection was carried out from mid-September to mid-October 2025, corresponding to the end of the rainy season and the beginning of the post-harvest period.

Source Population, Target Population, and Unit of Analysis

The source population consisted of households within enumeration areas established during the 2012 General Population and Housing Census. The target population comprised children aged 6–23 months living in selected households. The unit of analysis for this article was the individual child aged 6–23 months with complete dietary information required to classify child food poverty.

Sampling Design and Sample Size

A stratified two-stage cluster random sampling design was used, with each department and the municipality of Maradi City constituting an independent stratum.

In the first stage, clusters were selected systematically with probability proportional to population size within each stratum. In the second stage, a complete household listing was conducted within each selected cluster, followed by systematic selection of 15 households per cluster. Villages containing more than 150 households underwent prior geographical segmentation, after which one segment was selected to maintain a feasible and standardized field workload. The operational target was 420 households per stratum, corresponding to 28 clusters of 15 households and 3,780 households across the nine strata.

Following data collection, 1,353 children aged 6–23 months had been surveyed for the anthropometric and Infant and Young Child Feeding (IYCF) modules; complete dietary information for classification of child food poverty was available for 1,343 children. Sample size for the parent SMART survey was calculated using ENA for SMART (January 2020 version), assuming an expected global

acute malnutrition prevalence of 13.6% based on the 2022 national SMART survey in Maradi [15], an absolute precision of 3.5%, a 95% confidence level, a design effect of 1.06, and an anticipated non-response rate of 5%. These assumptions yielded the operational target of 420 households per stratum. The present article uses the final observed analytical population rather than the planned household sample size: 1,353 children were assessed, and 1,343 (99.3%) had complete dietary information for the child food poverty outcome.

Inclusion and Exclusion Criteria

Children aged 6–23 completed months who had resided in a randomly selected household for more than six months and whose caregiver provided informed consent were eligible. Children without the dietary information required to classify child food poverty were excluded from the corresponding analytical denominator.

Data Collection

Data were collected by 15 field teams, each comprising four trained fieldworkers, using electronic questionnaires programmed on tablets with automatic consistency checks, including skip patterns, range checks, and mandatory fields. The IYCF module included a structured 24-hour dietary recall documenting all foods and beverages consumed by the child during the previous day, regardless of the quantity consumed. Information was also collected on sociodemographic characteristics, recent morbidity, household conditions, and selected nutrition interventions. Several days of standardized training and continuous field supervision were used to promote consistency in administration of the survey instruments. Potential sources of bias included recall error and day-to-day variation in dietary intake inherent to a single 24-hour recall. These issues were addressed operationally through standardized interviewer training, a structured recall instrument, electronic consistency checks, and field supervision.

Measurement of Child Food Poverty

Child food poverty was derived from the 24-hour dietary recall. Foods and beverages consumed by the child were classified into the eight UNICEF/WHO food groups: (i) Breastmilk; (ii) Grains, roots, tubers and plantains; (iii) Pulses, nuts and seeds; (iv) Dairy products; (v) Flesh foods; (vi) Eggs; (vii) Vitamin A-rich fruits and vegetables; and (viii) Other fruits and vegetables.

Children consuming foods from 0–2 groups were classified as experiencing severe food poverty, those consuming 3–4 groups as experiencing moderate food poverty, and those consuming foods from ≥5 groups as experiencing no food poverty [10]. The child food poverty classification was based on the number of food groups consumed during the previous day. The analytical denominator was 1,343 children with complete dietary information. The 10 children without complete dietary information were excluded from analyses requiring the child food poverty outcome.

Minimum Dietary Diversity (MDD) was treated as a related but distinct binary indicator: children consuming foods from at least five of the eight food groups met the MDD threshold, whereas those consuming fewer than five groups did not. Because MDD and child food poverty are constructed from the same 24-hour dietary recall and the same eight food groups, MDD was retained for descriptive and bivariate analyses but was not included as an independent covariate in the final multinomial model.

Explanatory Variables

Potential explanatory variables were selected a priori on the basis of their epidemiological and programmatic relevance and included child age, child sex, recent diarrhea, maternal age, maternal education,

maternal marital status, household size, access to an improved drinking-water source, access to an improved latrine, place of residence, vitamin A supplementation, and deworming. MDD was not entered into the final multivariable model because of its direct conceptual overlap with the outcome definition. Deworming was examined in bivariate analysis but was not retained in the final multinomial model.

Statistical Analysis

Bivariate associations between explanatory variables and the three-category child food poverty outcome were assessed using Pearson's chi-square test. Multivariable associations were estimated using multinomial logistic regression, with no food poverty as the reference outcome category. Adjusted relative risk ratio (aRRR) and 95% confidence intervals were reported for moderate versus no food poverty and severe versus no food poverty.

The final model included 1,343 children and was evaluated using the Wald test. The model included child age, sex, recent diarrhea, maternal age, maternal education, marital status, household size, improved drinking water, improved latrine, residence, and vitamin A supplementation. No sampling weights or survey-adjusted variance estimates were applied because their use was not documented in the verified thesis analysis. This limitation should be considered when interpreting the precision of the estimated associations.

A multinomial rather than ordinal logistic regression model was retained because the analytical objective was to estimate separate adjusted associations for moderate and severe food poverty relative to no food poverty; the three categories were therefore not assumed to satisfy the proportional-odds assumption of an ordinal model. Statistical significance was defined as $p < 0.05$.

The statistical software used for the analyses was Stata; the version was not documented in the verified thesis records and therefore is not specified here. To investigate the urban–rural disparity in the prevalence of child food poverty, a linear Blinder–Oaxaca decomposition was performed on a binary outcome defined as the presence of moderate or severe food poverty versus no food poverty. The decomposition partitions the observed urban–rural prevalence gap into endowment, coefficient, and interaction components [17, 18].

For the decomposition, the observed gap was expressed as urban prevalence minus rural prevalence. The endowment component represents the portion associated with differences in the distribution of measured covariates, whereas the coefficient and interaction components reflect differences in estimated coefficients and their joint contribution to the statistical partition of the gap. These components were interpreted as descriptive statistical quantities rather than causal effects.

Results

Sociodemographic Characteristics of the Study Population

The regional sample included 1,353 children aged 6–23 months, distributed across the nine survey strata. Madarounfa contributed the largest number of children (221; 16.3%), whereas Maradi City contributed 97 (7.2%). The sex distribution was balanced at the regional level, with 684 boys (50.6%) and 669 girls (49.4%). Children aged 18–23 months represented the largest age group (38.0%), followed by those aged 12–17 months (31.9%) and 6–11 months (30.2%).

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Table 1. Sociodemographic Characteristics of Children Aged 6–23 Months by Geographic Unit (n = 1,353)

Department	n	% of Region	Girls (%)	Boys (%)	6–11 Months (%)	12–17 Months (%)	18–23 Months (%)
Aguié	128	9.5	55.5	44.5	32.8	24.2	43.0
Bermo	111	8.2	48.7	51.4	22.5	38.7	38.7
Dakoro	134	9.9	49.3	50.8	26.9	36.6	36.6
Gazaoua	173	12.8	46.2	53.8	30.6	31.2	38.2
Guidan-Roumdji	159	11.8	52.2	47.8	31.5	34.6	34.0
Madarounfa	221	16.3	52.0	48.0	33.9	31.7	34.4
Mayahi	165	12.2	47.9	52.1	24.2	32.7	43.0
Tessaoua	165	12.2	47.9	52.1	29.7	29.1	41.2
Maradi City	97	7.2	43.3	56.7	39.2	27.8	33.0
Region total	1,353	100.0	49.4	50.6	30.2	31.9	38.0

Note: *It describes the full surveyed sample (n = 1,353). Subsequent child food poverty analyses use 1,343 children with complete dietary information; analytical denominators may therefore differ.*

Magnitude of Child Food Poverty

Among the 1,343 children with complete dietary information, only 67 (5.0%) were classified as experiencing no child food poverty. A total of 586 children (43.6%) experienced moderate food poverty and 690 (51.4%) experienced severe food poverty. Thus, 95.0% of children were affected by moderate or severe child food poverty. More than half of the children were living in severe food poverty, consuming foods from no more than two of the eight defined food groups during the day preceding the survey. Moderate food poverty affected a further 43.6% of children, while only 5.0% consumed foods from at least five food groups. These thresholds correspond to the UNICEF child food poverty framework. Overall, 95.0% of children in the region were affected by moderate or severe child food poverty. The burden was therefore dominated by severe dietary deprivation rather than by moderate deprivation alone.

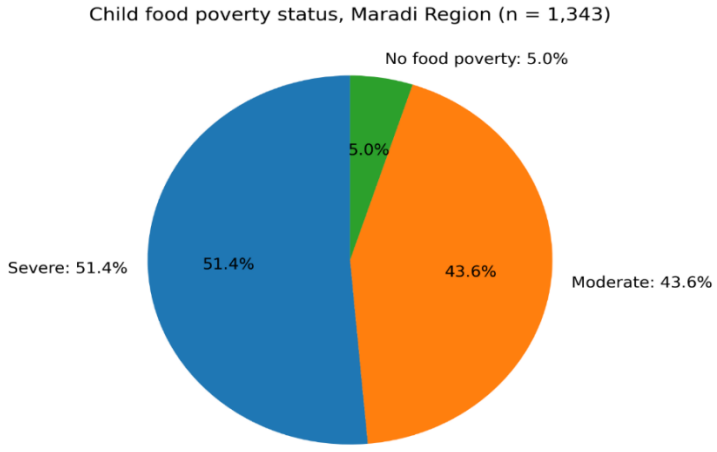


Figure 1. Distribution of Children Aged 6–23 Months According to Child Food Poverty Status, Maradi Region, Niger (n = 1,343)

Note: *Figure 1 displays the distribution of children across the three child food poverty categories. The predominance of severe food poverty indicates that the greatest share of children consumed foods from no more than two of the eight defined food groups during the preceding 24 hours.*

Table 2. Distribution of Children Aged 6–23 Months According to Child Food Poverty Category (n = 1,343)

Food Poverty Category (UNICEF 2024)	n	%	Definition (No. of Food Groups/8)
No food poverty	67	5.0	≥5 groups
Moderate food poverty	586	43.6	3–4 groups
Severe food poverty	690	51.4	0–2 groups
Total	**1,343**	**100.0**	—

Note: Child food poverty was classified according to the number of the eight defined food groups consumed during the previous 24 hours: no food poverty (≥5 groups), moderate food poverty (3–4 groups), and severe food poverty (0–2 groups).

Factors Associated with Food Poverty: Bivariate Analysis

In bivariate analysis, child food poverty was significantly associated with child age ($\chi^2(4) = 32.13$; $p < 0.001$). Severe food poverty affected 90.3% of children aged 6–11 months, compared with 49.9% of those aged 12–17 months and 44.0% of those aged 18–23 months.

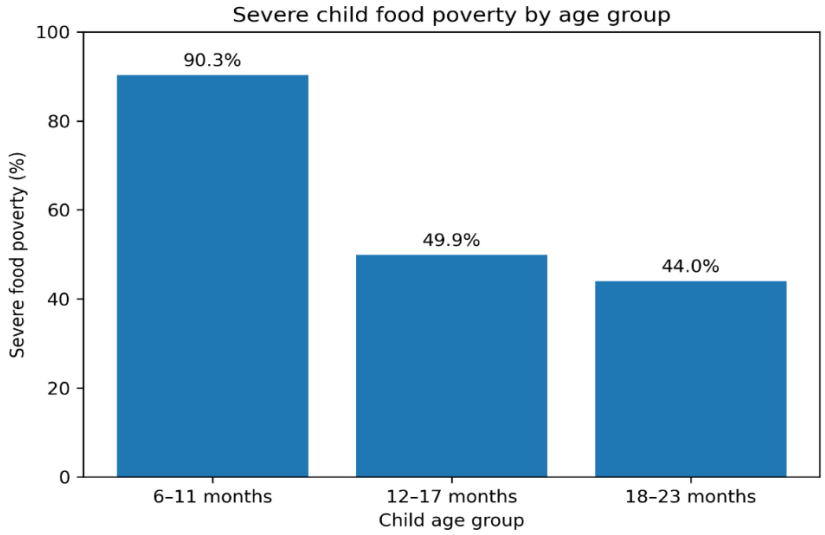


Figure 2. Prevalence of Severe Child Food Poverty by Age Group among Children Aged 6–23 Months, Maradi Region, Niger

Note: *Figure 2 illustrates the age gradient in severe child food poverty. The particularly high prevalence among children aged 6–11 months should be interpreted in the context of the transition to complementary feeding and the use of a single 24-hour dietary recall for classification.*

Significant associations were observed between child food poverty and recent diarrhea ($\chi^2(2) = 8.22$; $p = 0.016$), maternal education ($\chi^2(4) = 25.05$; $p < 0.001$), access to improved drinking water ($\chi^2(2) = 37.38$; $p < 0.001$), access to an improved latrine ($\chi^2(2) = 61.64$; $p < 0.001$), place of residence ($\chi^2(2) = 82.76$; $p < 0.001$), vitamin A supplementation ($\chi^2(2) = 12.47$; $p = 0.002$), and deworming ($\chi^2(2) = 17.40$; $p < 0.001$). The strongest bivariate geographic association was observed for place of residence, with substantially higher food poverty in rural than in urban areas. Access to improved water and sanitation was also strongly associated with food poverty status. The association between MDD and child food poverty was very strong ($\chi^2(2) = 512.38$; $p < 0.001$), as expected because both indicators are constructed from the same eight food groups and the same 24-hour dietary recall. MDD was therefore not interpreted as an independent determinant and was excluded

from the final multinomial model. No statistically significant associations were found between child food poverty and child sex ($\chi^2(2) = 2.13$; $p = 0.344$), maternal age ($\chi^2(4) = 5.64$; $p = 0.228$), marital status ($\chi^2(2) = 1.62$; $p = 0.446$), or household size ($\chi^2(6) = 8.73$; $p = 0.189$).

Table 3. Bivariate Associations (Pearson's chi-square) between Selected Characteristics and Child Food Poverty (n = 1,343)

Variable	No Food Poverty (n)	Moderate Food Poverty (n)	Severe Food Poverty (n)	χ^2	p-value
Child Age					
6–11 months	13	14	252	32.13	<0.001
12–17 months	20	195	214		
18–23 months	34	251	224		
Sex					
Female	29	283	353	2.13	0.344
Male	38	303	337		
Recent Diarrhea					
No	35	318	420	8.22	0.016
Yes	32	268	260		
Maternal Education					
None	41	419	553	25.05	<0.001
Primary	11	94	84		
Secondary+	15	73	53		
Marital Status					
Not in union	2	35	33	1.62	0.446
In union	65	551	657		
Household Size					
<5	20	162	210	8.73	0.189
5–9	37	314	323		
10–14	9	82	122		
>14	1	28	35		
Improved Drinking Water					
No	7	101	210	37.38	<0.001
Yes	63	485	480		
Improved Latrine					
No	31	426	580	61.64	<0.001
Yes	36	160	110		
Residence					
Urban	23	43	30	82.76	<0.001
Rural	44	543	660		

Vitamin A					
No	11	73	116	12.47	0.002
Yes	51	452	404		
Deworming					
No	12	101	150	17.40	<0.001
Yes	42	345	279		
MDD					
No	0	402	690	512.38	<0.001
Yes	67	184	0		

Note: Values are observed frequencies (n) in each food poverty category. χ^2 and p-values refer to the overall Pearson chi-square test across the three outcome categories. MDD is shown for descriptive/bivariate purposes because it is constructed from the same eight food groups as the child food poverty classification.

Adjusted Factors Associated with Child Food Poverty

After adjustment for child, maternal, household, environmental, and intervention-related characteristics, rural residence remained the strongest adjusted factor associated with both moderate and severe child food poverty. Compared with children living in urban areas, children living in rural areas had an aRRR of 7.20 (95% CI: 3.50–14.82; $p < 0.001$) for moderate food poverty and 14.69 (95% CI: 6.77–31.87; $p < 0.001$) for severe food poverty. Children aged 18–23 months had a lower relative risk ratio for severe food poverty than children aged 6–11 months (aRRR = 0.46; 95% CI: 0.22–0.98; $p = 0.044$). The corresponding association for moderate food poverty was not statistically significant (aRRR = 0.61; 95% CI: 0.29–1.30; $p = 0.199$). The 12–17-month age group was not significantly associated with either moderate or severe food poverty. No statistically significant adjusted association was observed for household size, although estimates for households of more than 14 persons were imprecise. The association between an improved latrine and severe food poverty was inverse but did not reach statistical significance (aRRR = 0.54; 95% CI: 0.26–1.14; $p = 0.107$).

Sex, recent diarrhea, maternal age, maternal education, marital status, improved drinking water, and vitamin A supplementation were not independently associated with moderate or severe food poverty after adjustment. In particular, the bivariate association observed for maternal education did not persist in the final multivariable model. The final multinomial logistic regression model was statistically significant (Wald $\chi^2(32) = 380.70$; $p < 0.001$; $n = 1,343$). The adjusted associations are presented in Table 4.

Table 4. Adjusted Relative Risk Ratios (aRRRs) for Moderate and Severe Child Food Poverty, with No Food Poverty as the Reference Category (n = 1,343)

Variable	Moderate Food Poverty aRRR [95% CI]	p-value	Severe Food Poverty aRRR [95% CI]	p-value
Age				
6–11 months	1.00 (ref.)	—	1.00 (ref.)	—
12–17 months	0.84 [0.37–1.90]	0.678	0.77 [0.34–1.75]	0.539
18–23 months	0.61 [0.29–1.30]	0.199	0.46 [0.22–0.98]	0.044
Sex				

Female	1.00 (ref.)	—	1.00 (ref.)	—
Male	0.96 [0.58–1.60]	0.874	0.86 [0.51–1.44]	0.560
Recent Diarrhea				
No	1.00 (ref.)	—	1.00 (ref.)	—
Yes	1.05 [0.62–1.77]	0.856	0.82 [0.48–1.39]	0.455
Maternal Age				
<20 years	1.00 (ref.)	—	1.00 (ref.)	—
20–34 years	1.47 [0.65–3.32]	0.352	1.80 [0.79–4.10]	0.160
≥35 years	1.57 [0.60–4.10]	0.354	1.65 [0.62–4.38]	0.315
Maternal Education				
None	1.00 (ref.)	—	1.00 (ref.)	—
Primary	1.29 [0.60–2.73]	0.514	1.04 [0.48–2.25]	0.916
Secondary+	1.42 [0.66–3.06]	0.370	1.09 [0.49–2.41]	0.840
Marital Status				
Not in union	1.00 (ref.)	—	1.00 (ref.)	—
In union	0.95 [0.39–2.35]	0.913	1.64 [0.64–4.18]	0.298
Household Size				
<5 persons	1.00 (ref.)	—	1.00 (ref.)	—
5–9 persons	1.42 [0.77–2.61]	0.256	1.24 [0.67–2.29]	0.491
10–14 persons	1.47 [0.60–3.62]	0.404	1.95 [0.79–4.83]	0.147
>14 persons	4.40 [0.53–36.40]	0.169	4.91 [0.59–41.08]	0.142
Improved Drinking Water				
No	1.00 (ref.)	—	1.00 (ref.)	—
Yes	1.22 [0.59–2.53]	0.597	0.81 [0.39–1.68]	0.577
Improved Latrine				
No	1.00 (ref.)	—	1.00 (ref.)	—
Yes	0.72 [0.34–1.49]	0.372	0.54 [0.26–1.14]	0.107
Residence				
Urban	1.00 (ref.)	—	1.00 (ref.)	—
Rural	7.20 [3.50–14.82]	<0.001	14.69 [6.77–31.87]	<0.001
Vitamin A				
No	1.00 (ref.)	—	1.00 (ref.)	—
Yes	1.16 [0.58–2.33]	0.673	0.58 [0.29–1.16]	0.121

Note: aRRR = adjusted relative risk ratio; 95% CI = 95% confidence interval; ref. = reference category. aRRRs compare moderate or severe food poverty with no food poverty while holding the other variables in the model constant. Estimates for households with >14 persons should be interpreted cautiously because of their wide confidence intervals.

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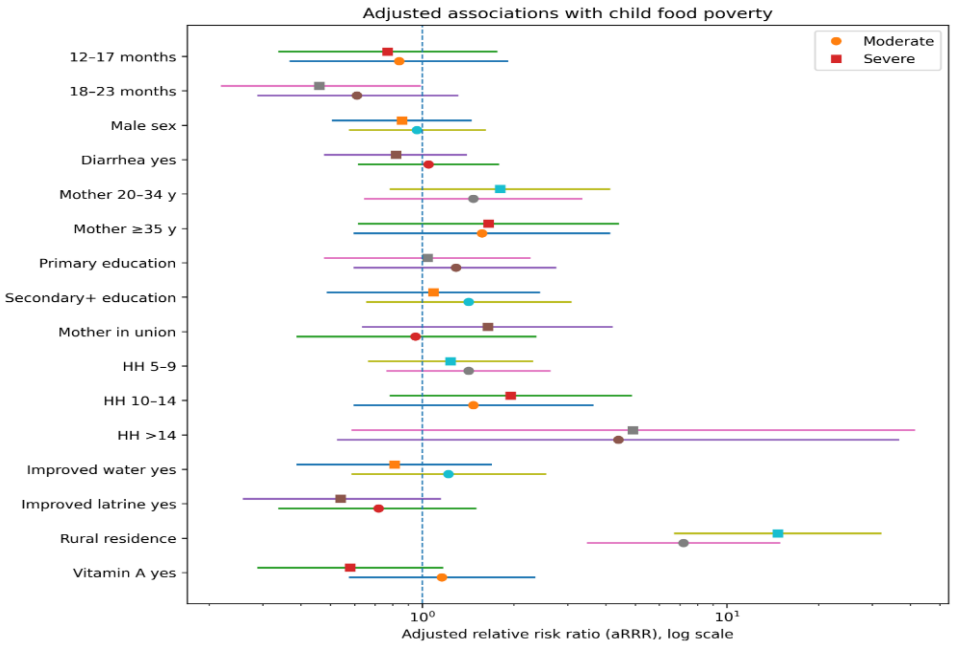


Figure 3. Adjusted Associations between Selected Characteristics and Moderate and Severe Child Food Poverty, Maradi Region, Niger (Multinomial Logistic Regression; aRRRs with 95% CI)

Note: *Points represent adjusted relative risk ratios (aRRRs) and horizontal lines represent 95% confidence intervals. Values >1 indicate higher relative risk relative to no food poverty, whereas values <1 indicate lower relative risk; the vertical reference line corresponds to aRRR = 1.*

Blinder–Oaxaca Decomposition of the Urban–Rural Gap

Child food poverty affected 75.6% of children in urban areas (72/96) and 95.3% of children in rural areas (1,189/1,247), corresponding to a crude urban–rural prevalence gap of −0.197 (19.7 percentage points; $p < 0.001$), expressed as urban minus rural prevalence. Thus, the prevalence was 19.7 percentage points higher in rural than in urban areas. The endowment component was 0.021 (SE = 0.020; $p = 0.284$) and was not statistically significant, indicating that the measured differences in observed characteristics did not, by themselves, account for a statistically significant portion of the urban–rural prevalence gap.

The coefficient component was −0.558 (SE = 0.166; $p = 0.001$), and the interaction component was 0.340 (SE = 0.166; $p = 0.040$). These components should be interpreted as statistical partitions of the observed gap rather than causal effects. The three decomposition components sum to the observed crude gap: $0.021 - 0.558 + 0.340 = -0.197$. The results therefore do not support the interpretation that approximately 21% of the disparity is explained by measured household characteristics, nor do they justify attributing the remaining disparity directly to unmeasured contextual factors. Because the decomposition is based on a cross-sectional prevalence comparison, the coefficient and interaction components reflect differences in estimated associations between urban and rural groups and should not be interpreted as causal mechanisms.

Table 5. Blinder–Oaxaca Decomposition of the Urban–rural Prevalence Gap in Child Food Poverty, Expressed as Urban Minus Rural Prevalence (n = 1,343)

Component	Coefficient	Standard Error	p-value
Food poverty prevalence–urban (n = 96)	0.756	0.046	<0.001
Food poverty prevalence–rural (n = 1,247)	0.953	0.007	<0.001
Crude gap (urban–rural)	−0.197	0.047	<0.001
Endowment component	0.021	0.020	0.284
Coefficient component	−0.558	0.166	0.001
Interaction term	0.340	0.166	0.040

Note Table 5: *The crude urban–rural gap is expressed as urban prevalence minus rural prevalence. The endowment, coefficient, and interaction components are statistical partitions of the observed gap and should not be interpreted as causal effects. The three components sum to the observed gap (0.021 − 0.558 + 0.340 = −0.197).*

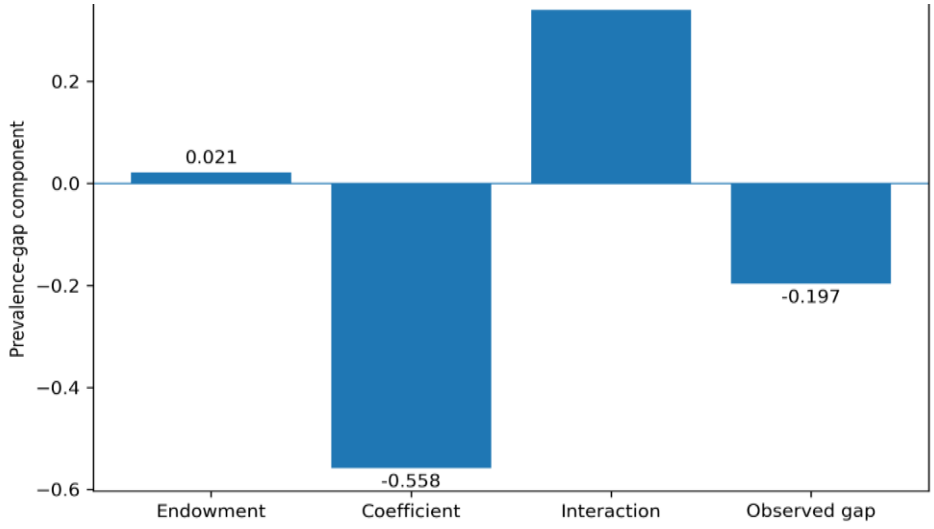


Figure 4. Blinder–Oaxaca decomposition of the urban–rural prevalence gap in child food poverty, Maradi Region, Niger

Note: *The three components sum to the observed urban–rural prevalence gap (0.021 − 0.558 + 0.340 = −0.197). Because the analysis is cross-sectional, the decomposition describes the statistical structure of the observed disparity and does not identify causal mechanisms.*

Discussion

Magnitude of Child Food Poverty

To our knowledge, this study is among the first to apply the UNICEF child food poverty framework to a subregional population in Niger and to examine the urban–rural disparity using a Blinder–Oaxaca decomposition. The findings show an exceptionally high burden of child food poverty, with severe food poverty predominating, and a strong adjusted association with rural residence.

The proportion of children experiencing no child food poverty in the Maradi region was only 5.0%, while 43.6% experienced moderate and 51.4% severe child food poverty. Thus, 95.0% experienced moderate or severe child food poverty. This represents a substantial level of dietary deprivation and indicates that severe food poverty is not a marginal subgroup but the predominant category in this population. More than half of the children consumed foods from no more than two of the eight food groups during the 24 hours preceding the survey.

Comparisons with other settings should nevertheless be made cautiously because published studies may differ in age range, survey design, timing, food-group definitions, and operationalization of child food poverty. A complementary analysis of the same study population found that 18.7% of children met the minimum dietary diversity threshold. The higher proportion meeting MDD than the proportion classified as experiencing no child food poverty is expected because MDD and child food poverty use the same eight food groups but apply different classifications. MDD is a binary indicator based on consuming foods from at least five of the eight food groups, whereas the child food poverty framework distinguishes moderate and severe dietary deprivation among children consuming fewer than five groups.

The magnitude observed in Maradi is also consistent with evidence from other Sahelian settings reporting substantial dietary deprivation among young children. [7-9, 20]. UNICEF's 2024 global assessment identified Niger among the countries carrying a particularly large burden of severe child food poverty [5, 10, 11].

The Age Gradient

Severe child food poverty was highest among children aged 6–11 months (90.3%) and declined to 49.9% among those aged 12–17 months and 44.0% among those aged 18–23 months. This age gradient is consistent with the transition toward complementary feeding after six months, but the cross-sectional design does not establish a causal effect of age or feeding practices.

The very high prevalence among children aged 6–11 months may reflect the early stage of complementary feeding and the limited diversification of diets during this transition, consistent with previous evidence from low- and middle-income countries [1, 2, 20]. However, the present data cannot distinguish developmental, behavioral, household, or seasonal explanations for the observed gradient. These findings support strengthening age-appropriate complementary-feeding counselling from six months onward, while avoiding the inference that the observed age gradient alone identifies a specific causal intervention target.

The Dominant Role of Place of Residence

One of the most important findings was the persistence of a strong association between rural residence and child food poverty after multivariable adjustment. Compared with children living in urban areas, children living in rural areas had an aRRR of 7.20 (95% CI: 3.50–14.82; $p < 0.001$) for moderate child food poverty and 14.69 (95% CI: 6.77–31.87; $p < 0.001$) for severe child food poverty. Rural residence was therefore the strongest adjusted factor associated with both moderate and severe child food poverty in the final multinomial model.

This finding is consistent with evidence from sub-Saharan Africa showing geographic and socioeconomic inequalities in young children's dietary diversity. Previous studies have demonstrated that rural residence, household poverty, limited maternal access to information, and reduced market access are associated with poorer dietary diversity among young children [7, 9, 13, 14, 21]. However, the present cross-sectional analysis cannot determine which specific rural mechanisms, such as household resources, food availability, market access, sanitation, or social norms, produce the observed disparity.

The Blinder–Oaxaca decomposition adds an important qualification to this finding. Child food poverty affected 75.6% of children in urban areas and 95.3% of children in rural areas, corresponding to a crude urban–rural prevalence gap of −0.197 (19.7 percentage points), expressed as urban minus rural prevalence. Thus, the prevalence of child food poverty was 19.7 percentage points higher in rural than in urban areas. The endowment

component was 0.021 (SE = 0.020; p = 0.284) and was not statistically significant. This indicates that differences in the distribution of the measured characteristics included in the decomposition did not, by themselves, account for a statistically significant portion of the observed urban–rural prevalence gap.

The coefficient component was −0.558 (SE = 0.166; p = 0.001), while the interaction component was 0.340 (SE = 0.166; p = 0.040). The three components sum to the observed crude gap (0.021 − 0.558 + 0.340 = −0.197). These decomposition components should be understood as statistical partitions of the observed prevalence difference rather than causal effects. In particular, the results do not support describing approximately 21% of the disparity as being "explained" by measured household characteristics, nor do they justify attributing the remaining disparity directly to unmeasured contextual factors.

Because the decomposition is based on a cross-sectional prevalence comparison, the coefficient and interaction components reflect differences in estimated associations between urban and rural groups and their joint contribution to the statistical partition of the observed gap. They should therefore not be interpreted as causal mechanisms or as direct measures of unobserved contextual factors.

Although maternal education was not independently associated with child food poverty in the present study, previous studies have reported positive associations between maternal education and improved infant and young child feeding practices [13, 14, 20]. This distinction is important because the data do not support a claim of an independent protective effect of maternal education in the final model. Accordingly, interventions should not be justified solely on the basis of maternal education as an independent factor in this dataset. Education may still be relevant to nutrition programming, but its role requires interpretation within the broader socioeconomic and structural context.

Limitations and Implications

This study has several limitations. First, its cross-sectional design does not permit causal inference regarding the relationships between the characteristics studied and child food poverty. The observed associations should therefore be interpreted as correlational rather than causal.

Second, child food poverty relies on a single 24-hour dietary recall and may therefore be affected by recall or reporting errors and by day-to-day and seasonal variation in food consumption. The use of a single recall also limits the ability to distinguish usual dietary intake from short-term variation. This limitation is particularly relevant when interpreting the strong relationship between child food poverty and MDD because both indicators are derived from the same dietary information. Their conceptual and measurement overlap explains the strong bivariate association and supports the decision not to include MDD in the final multivariable model.

Third, several potentially relevant factors, including detailed household wealth, household food security, food prices, market access, and broader characteristics of the local food environment, were not available for the final analysis. Their absence limits the ability to fully characterize the socioeconomic and structural pathways underlying child food poverty.

Fourth, although the study used a stratified cluster sampling design, the verified thesis analysis did not document the application of sampling weights or survey-adjusted variance estimation. Consequently, the reported confidence intervals and p-values should be interpreted with this analytical limitation in mind.

Finally, the Blinder–Oaxaca decomposition provides a statistical partition of the observed urban–rural disparity and does not establish causal mechanisms. In particular, a statistically significant coefficient or interaction component

does not identify a specific unmeasured determinant or causal pathway.

Despite these limitations, the study provides regionally disaggregated evidence on child food poverty using a recent international framework and identifies rural residence and early age as key correlates that merit attention in nutrition policy and programming. Given the particularly high prevalence of severe food poverty among children aged 6–11 months, complementary-feeding counselling and support should be strengthened from six months of age, alongside broader measures that improve access to diverse and nutritious foods, consistent with WHO, UNICEF, and nutrition-sensitive programming recommendations [1, 19, 22]. Nutrition programming should also consider the broader rural socioeconomic and food-system context rather than focusing on individual-level characteristics alone, including food affordability, agricultural diversification, market accessibility, and social protection interventions [6, 11, 19, 23].

Future studies should incorporate longitudinal designs and more detailed measures of household economic resources, food security, food environments, market access, food prices, and seasonal variation to clarify the pathways underlying child food poverty and geographic disparities. Further research is also needed to determine whether the observed urban–rural disparity persists across seasons and to better characterize the contextual factors contributing to the particularly high burden of severe child food poverty in rural areas.

Conclusion

Using the UNICEF child food poverty framework, this study found a very high burden of child food poverty among children aged 6–23 months in the Maradi region, with 95.0% experiencing moderate or severe child food poverty and 51.4% experiencing severe child food poverty. Severe food poverty was particularly pronounced among children aged 6–11 months, among whom 90.3% were classified as experiencing severe child food poverty. Rural residence was the strongest adjusted factor associated with both moderate and severe child food poverty, with adjusted relative risk ratios of 7.20 and 14.69, respectively.

These findings highlight the need to strengthen complementary-feeding counselling and support from six months of age, particularly in rural areas, while promoting sustained access to diverse and nutritious foods in accordance with global recommendations on child nutrition and complementary feeding [1, 19, 22].

However, the cross-sectional design does not permit causal inference, and the Blinder–Oaxaca decomposition should be interpreted as a statistical partition of the observed urban–rural disparity rather than as evidence of causal mechanisms.

Programmatic responses should therefore extend beyond individual feeding practices and consider the broader socioeconomic and food-system context, including household economic conditions, food availability and affordability, market access, food security, and other contextual determinants, as highlighted in recent global nutrition and food security reports [6, 11, 23, 24]. Further research, particularly longitudinal studies incorporating detailed measures of household wealth, food security, food prices, market access, food environments, and seasonality, is needed to clarify the pathways underlying child food poverty and the urban–rural disparity observed in the Maradi region.

Conflict of Interest

The authors declare that they have no conflict of interest related to this study. All authors reviewed and approved the final manuscript.

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Ethical Approval

Ethical approval for this study was obtained from the National Health Research Ethics Committee of Niger. Administrative authorization was also secured from relevant regional and local health authorities. Written informed consent was obtained from caregivers before participation. All collected data were anonymized prior to analysis, and confidentiality was maintained throughout the study.

Authors' Contributions

All authors contributed to the conception and design of the study, data analysis and interpretation, and drafting or critical revision of the manuscript. All authors reviewed and approved the final version of the manuscript.

Data Availability

The dataset analyzed during the current study is not publicly available due to data governance and confidentiality requirements. However, anonymized data may be made available by the corresponding author upon reasonable request and subject to the necessary approvals.

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Enhancing Surgical Safety in a Newly Established Cardiothoracic Center Using Failure Modes and Effects Analysis for Improving Outcomes in East Africa

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Abstract *Surgical safety is a major patient safety priority, especially in high-risk specialties such as cardiothoracic surgery. Newly established centers in low-resource settings may face amplified risks from communication failures, inconsistent perioperative processes, equipment readiness gaps, delayed blood product availability, and delayed recognition of postoperative deterioration. This quality improvement study evaluated the use of Failure Modes and Effects Analysis (FMEA) to improve surgical safety in a newly established cardiothoracic and vascular center in East Africa. A prospective 12-month quality improvement study was conducted at Kalkaal Hospital Cardiothoracic and Vascular Center, Mogadishu, Somalia. A multidisciplinary team mapped the perioperative pathway, identified potential failure modes, scored risks using severity, occurrence, and detection ratings, calculated Risk Priority Numbers, and prioritized corrective interventions. Baseline and post-intervention indicators included surgical safety checklist compliance, equipment-related operative delays, structured handoff compliance, postoperative deterioration escalation time, ICU readmissions, and safety culture indicators. Twenty-one potential failure modes were identified. Five high-priority risks were selected for intervention: inadequate patient verification, delayed recognition of postoperative deterioration, equipment readiness failure, communication failure during handoff, and checklist noncompliance. Interventions included a cardiothoracic-adapted checklist, equipment readiness bundle, standardized handoff tool, ICU early warning escalation algorithm, daily safety huddles, and briefing/debriefing protocols. Checklist compliance improved from 72% to 96%, equipment delay events reduced from 10 to 6 per month, structured handoff compliance improved from 61% to 92%, median escalation time improved from 42 to 18 minutes, and ICU readmissions were eliminated during observation. FMEA was feasible and useful for strengthening surgical safety in this setting.*

Keywords *Cardiothoracic Surgery, Failure Modes and Effects Analysis, Patient Safety, Quality Improvement, Surgical Safety.*

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Introduction

Patient safety remains a foundational dimension of healthcare quality and a core requirement for trustworthy health systems. The World Health Organization Global Patient Safety Action Plan 2021–2030 identifies avoidable harm in healthcare as a major global priority and calls for safer clinical processes, stronger safety culture, incident learning, leadership accountability, patient engagement, and continuous quality improvement across health systems [1, 7-11]. Surgical care is particularly high risk because it involves multiple transitions, invasive procedures, anesthesia-related hazards, complex equipment, infection risks, blood product requirements, and postoperative deterioration risks [2, 6-8, 28]. International surgical safety frameworks provide an important foundation for this study. The WHO Surgical Safety Checklist, developed through the Safe Surgery Saves Lives initiative, remains one of the most widely adopted tools for improving perioperative safety. Contemporary reviews continue to show that surgical safety checklists can improve team communication, standardize critical safety checks, reduce omissions, and strengthen perioperative safety culture when implemented with training, leadership support, audit, feedback, and local adaptation [3-6, 20, 21, 29, 30]. However, checklist implementation is not simply a documentation exercise. Its effectiveness depends on integration into team communication, operating room workflow, leadership, organizational culture, and local resource realities [3-5, 9, 20, 21].

Surgical safety challenges are especially important in low- and middle-income countries, where health systems may face workforce shortages, limited equipment availability, variable documentation systems, constrained intensive care capacity, and inconsistent access to essential perioperative resources [5, 6, 28]. Recent evidence from Somalia shows that implementation of the WHO Surgical Safety Checklist remains important but challenging in resource-limited hospitals, with barriers including gaps in training, staff awareness, adherence, supervision, and institutional support [6]. These challenges are highly relevant to newly established specialist surgical centers, where teams, protocols, documentation systems, and safety routines may still be developing. Cardiothoracic surgery presents additional safety risks because it requires coordinated work among surgeons, anesthetists, perfusion staff, theatre nurses, ICU clinicians, biomedical engineers, blood bank staff, and postoperative care teams. Small delays or communication failures may become clinically significant because patients are often physiologically unstable, procedures depend on complex equipment, and postoperative deterioration may progress rapidly. Therefore, cardiothoracic services require reliable patient verification, blood product readiness, equipment checks, sterile technique, structured handoff, high-acuity monitoring, and rapid escalation pathways [6, 22, 23, 28].

The East African context further justified this intervention. Kalkaal Hospital Cardiothoracic and Vascular Center was newly established in Mogadishu, Somalia, and institutional service data showed 10,654 emergency encounters, 49,262 outpatient visits, and 5,349 inpatient admissions, with trauma and surgical cases constituting approximately 65% of the clinical burden. These figures indicate substantial surgical and emergency care demand and highlight the need to embed safety systems early in the development of specialized services.

Failure Modes and Effects Analysis is a proactive risk-assessment method used to identify where and how a process might fail before harm occurs. In healthcare, FMEA supports systematic process mapping, failure-mode identification, risk scoring, prioritization,

and design of preventive controls [16-19]. Unlike retrospective incident review, FMEA is preventive and is therefore well-suited to newly established high-risk services where waiting for adverse events to accumulate would be unsafe and ethically problematic. This study was conceptually grounded in a systems approach to patient safety, which recognizes that harm usually results from interactions among people, tasks, tools, technologies, organizational culture, and resource constraints rather than from individual error alone [1, 7-11]. The study also drew on quality improvement principles emphasizing context, measurement over time, intervention fidelity, and transparent reporting of improvement work [12-15, 27]. The Donabedian structure–process–outcome model informed the selection of indicators: structural elements included staffing, equipment availability, and protocols; process measures included checklist compliance, equipment-readiness checks, structured handoff, safety huddles, and escalation compliance; and outcome indicators included equipment-related delays, escalation time, ICU readmissions, and safety-culture measures.

Despite growing global attention to surgical safety, important evidence gaps remain. First, most surgical safety checklists and perioperative quality improvement studies focus on general surgical settings rather than high-risk cardiothoracic services. Second, fewer studies describe proactive risk assessment in newly established specialist centers in fragile or resource-constrained African settings. Third, limited evidence exists on how FMEA can be used to design locally feasible cardiothoracic safety interventions in Somalia or similar East African settings. Fourth, many studies report checklist compliance without adequately examining related safety processes such as equipment readiness, handoff reliability, postoperative escalation, sustainability, and safety culture [3-6, 16-19, 22, 28]. This study addresses these gaps by evaluating an FMEA-guided surgical safety intervention bundle in a newly established cardiothoracic and vascular center in Mogadishu, Somalia. The novelty of the study lies in applying proactive risk assessment to a new high-acuity specialty service and linking identified risks to locally feasible interventions, including a cardiothoracic-adapted checklist, equipment-readiness bundle, structured handoff protocol, ICU early warning escalation algorithm, safety huddles, and briefing/debriefing practices.

Study Aim

This study aimed to enhance surgical safety through the application of Failure Modes and Effects Analysis in a newly established cardiothoracic center in East Africa.

Specific Objectives

1. To identify high-risk failure modes across the perioperative pathway.
2. To prioritize identified risks using Risk Priority Numbers.
3. To implement targeted interventions to mitigate priority risks.
4. To evaluate changes in selected surgical safety indicators following intervention.
5. To generate lessons for strengthening quality systems in emerging specialty centers.

Methods

Study Design

The study was a single-center prospective quality improvement study using a quasi-experimental pre–post intervention design. Failure Modes and Effects Analysis was used as the core prospective risk-assessment framework. Baseline safety indicators were measured before implementation, followed by introduction of a multicomponent surgical safety intervention bundle and post-intervention assessment [16-19]. The study was not randomized and did not

include a parallel control group. Therefore, findings are interpreted as evidence of an association between the intervention bundle and improved safety-process indicators, rather than definitive evidence of causality. The reporting approach was guided by contemporary quality improvement reporting principles, including a clear description of context, intervention components, measures, analysis, limitations, and implications for sustainability and spread [12-15, 27].

Study Setting

The study was conducted at Kalkaal Hospital Cardiothoracic and Vascular Center in Mogadishu, Somalia. The center is a newly established specialist referral service providing adult and selected pediatric cardiothoracic and vascular services, including open-heart procedures, thoracic surgery, perioperative care, intensive care support, and postoperative follow-up. Institutional service data included 10,654 emergency encounters, 49,262 outpatient visits, and 5,349 inpatient admissions, with trauma and surgical cases constituting approximately 65% of the case burden. These figures reinforced the importance of strengthening surgical safety processes and provided the operational context for this quality improvement initiative.

The center was in an early developmental phase during the study period. Multidisciplinary teams had recently been recruited, clinical protocols were being standardized, and documentation systems were evolving. This made the center an appropriate setting for proactive risk assessment because many workflows were still adaptable, and improvement interventions could be incorporated before unsafe routines became normalized.

Study Population, Eligibility Criteria and Sampling

The study population included patients undergoing cardiothoracic, thoracic, vascular, or related high-risk surgical procedures at Kalkaal Hospital Cardiothoracic and Vascular Center during the baseline and post-intervention audit periods. Staff participants included cardiothoracic surgeons, anesthetists, operating theatre nurses, ICU nurses, perfusion staff, biomedical engineering personnel, infection prevention staff, and quality improvement personnel involved in the perioperative pathway.

Patients were included if they underwent eligible cardiothoracic, thoracic, vascular, or related high-risk procedures during the study period and had perioperative documentation available for review. Patients were excluded if they were managed outside the cardiothoracic and vascular pathway, had incomplete records for the specific indicator being assessed, or were transferred out before postoperative assessment could be completed.

Staff were included if they were directly involved in perioperative, ICU, biomedical, or quality improvement processes related to the intervention. Staff not involved in the perioperative pathway or who declined participation in feedback activities were excluded from staff survey components. A consecutive sampling approach was used for eligible surgical cases during the baseline and post-intervention audit periods. No formal power calculation was conducted because this was a pragmatic quality improvement study designed to assess feasibility, implementation fidelity, and direction of change in safety indicators. The sample size was determined by the number of eligible cases, audits, and staff observations available during the predefined 12-month project period. This limitation is acknowledged because the study

may have been underpowered to detect changes in rare clinical outcomes.

Study Period

The project was implemented over 12 months. The baseline assessment phase lasted two months and focused on observing current practice, collecting audit data, reviewing incident trends, and identifying process gaps. The FMEA risk analysis phase lasted two months and involved multidisciplinary process mapping, failure mode identification, scoring, and prioritization. Intervention implementation was conducted over five months. Post-intervention evaluation occurred over three months, with repeated audit measurements, review of outcome indicators, and feedback from staff.

FMEA Team Composition

A multidisciplinary quality improvement team was constituted to reflect the full perioperative pathway. The team included cardiothoracic surgeons, cardiac anesthetists, critical care nurses, operating theatre nurses, perfusion specialists, a biomedical engineer, an infection prevention officer, a quality improvement coordinator, and a hospital leadership representative. The inclusion of diverse professional groups was important because each group had unique knowledge of process vulnerabilities. For example, theatre nurses contributed practical knowledge about checklist completion and sterile preparation, biomedical engineering staff identified equipment readiness gaps, ICU nurses described deterioration recognition challenges, and surgeons and anesthetists clarified intraoperative risks and decision points.

FMEA Process

Process Mapping

The perioperative pathway was mapped from admission through discharge. The mapped stages included preoperative assessment, patient identification and consent verification, blood product preparation, surgical scheduling, theatre preparation, anesthesia induction, surgical time-out, intraoperative monitoring, equipment use, transfer to ICU, postoperative monitoring, handoff transitions, step-down care, discharge planning, and follow-up. Critical interfaces and dependencies were highlighted because failures often occur during transitions rather than during isolated technical tasks. The overall FMEA workflow used in the project is summarized in Figure 1.

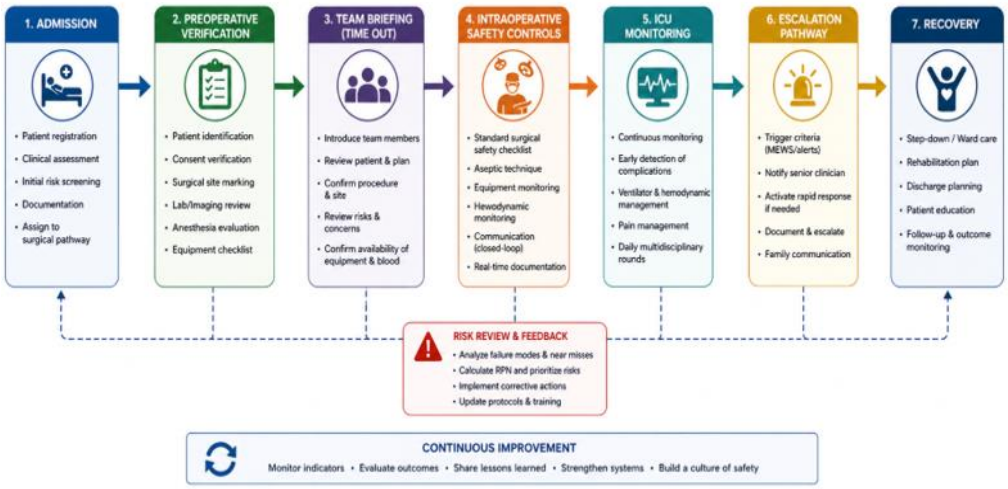


Figure 1. FMEA Surgical Safety Workflow Model

Failure Mode Identification

Potential failure modes were identified through team brainstorming sessions, process walkthroughs, direct observation, review of incident and near-miss trends, selected root cause analysis outputs, and frontline staff feedback. The team deliberately included both actual and potential risks because the purpose of FMEA was to prevent future harm, not only to respond to events that had already occurred.

Examples of identified failure modes included incomplete patient verification, incomplete consent documentation, delayed blood product availability, missing equipment checks, perfusion equipment readiness failures, delayed recognition of postoperative deterioration, incomplete handoff from operating theatre to ICU, inconsistent checklist use, unclear escalation pathways, delayed response to abnormal vital signs, incomplete documentation of critical intraoperative events, and inadequate preoperative communication between departments.

Risk Scoring

Each failure mode was scored using three standard FMEA domains: severity, occurrence, and detection. Severity reflected the potential level of harm if the failure occurred. Occurrence reflected the estimated likelihood of the failure occurring. Detection reflected the likelihood that the failure would not be detected before causing harm, with higher detection scores indicating weaker detectability. Each domain was scored from 1 to 10. The Risk Priority Number was calculated as follows:

Risk Priority Number = Severity × Occurrence × Detection

High-risk thresholds were defined prospectively. Failures with high severity and high RPN were prioritized for immediate intervention. The five highest-priority failure modes are presented in Table 1.

Intervention Development

The intervention consisted of a multicomponent surgical safety bundle developed from the five highest-priority FMEA risks. The bundle included a cardiothoracic-adapted surgical safety checklist, equipment-readiness verification bundle, structured handoff protocol, ICU early warning escalation algorithm, daily safety huddles, and briefing/debriefing practices. These components were consistent with patient safety principles emphasizing standardization, communication, early detection of risk, team situational awareness, human factors, and system-level prevention [1, 3, 7-9, 20-22].

The team designed a bundle of practical, resource-sensitive interventions targeting the highest-priority failure modes. The interventions were selected because they were feasible within existing resources, aligned with patient safety principles, and could be implemented quickly without requiring major infrastructure expansion.

First, a cardiothoracic-adapted surgical safety checklist was introduced. This checklist retained core elements of the standard surgical safety checklist but added cardiothoracic-specific prompts, including confirmation of blood product availability, perfusion readiness where applicable, implant or graft readiness, high-risk medication availability, airway and hemodynamic concerns, postoperative ICU bed readiness, and anticipated complications.

Second, an equipment readiness verification bundle was introduced. This bundle required preoperative verification of critical theatre equipment, anesthesia equipment, perfusion-related equipment where applicable, suction, oxygen supply, monitoring devices, defibrillator availability, warming devices, and backup plans for essential equipment. The biomedical engineer

participated in scheduled readiness checks and helped document recurrent equipment issues.

Third, a standardized structured handoff protocol was implemented for transfer from the operating theatre to the ICU and from the ICU to step-down care. The handoff tool required communication of patient identity, procedure performed, intraoperative events, hemodynamic concerns, blood products used, airway status, drains and lines, medications and infusions, pending investigations, anticipated complications, and escalation triggers.

Fourth, an early warning escalation algorithm was introduced in the ICU. The algorithm defined abnormal vital-sign thresholds, clinical-deterioration triggers, escalation timelines, responsible responders, and documentation requirements. It also supported earlier recognition of bleeding, arrhythmias, respiratory compromise, neurological changes, and hemodynamic instability.

Fifth, daily safety huddles and team briefing/debriefing protocols were introduced. Preoperative huddles created a shared plan before high-risk cases, while postoperative debriefings identified lessons, near misses, equipment issues, communication problems, and improvement actions. These huddles also strengthened safety culture by normalizing speaking up and reporting hazards.

The driver diagram in Figure 6 illustrates the relationship between the project aim, primary drivers, secondary drivers, and change ideas. The implementation timeline is shown in Figure 7.

Study Variables

Primary outcome and process indicators included surgical safety checklist compliance, equipment-related operative delays, ICU readmissions, postoperative adverse event detection, median time to escalation for deterioration, and structured handoff compliance. Secondary indicators included staff perceptions of teamwork, communication reliability, confidence in reporting safety concerns, and compliance with safety huddle documentation.

Data Collection

Measurement Tools and Operational Definitions

Data were collected using structured audit forms developed from the intervention components and reviewed by the multidisciplinary FMEA team for content validity. Tools included a checklist-compliance audit form, equipment-delay log, structured handoff audit tool, ICU escalation-time form, safety huddle documentation form, and staff safety-culture feedback form.

To improve reliability, audit definitions were standardized before data collection. The quality improvement coordinator oriented auditors on the meaning of each indicator, and selected records were cross-checked with theatre logs, ICU records, and checklist documentation.

Operational definitions were as follows:

- **Checklist compliance:** Proportion of eligible surgical cases in which all required checklist phases were completed and documented.
- **Equipment-related delay:** Any delay in surgical start or intraoperative workflow attributed to missing, unavailable, malfunctioning, or unverified equipment.
- **Structured handoff compliance:** Proportion of eligible transfers in which the required handoff elements were communicated and documented.
- **Escalation time:** Time in minutes from first documented abnormal trigger or deterioration sign to notification or review by the responsible clinician.
- **ICU readmission:** Unplanned return to ICU after transfer to a lower-acuity area during the same postoperative admission.

- **Safety huddle compliance:** Proportion of eligible operating days or high-risk cases with documented preoperative huddle completion.

Timing of Assessments

Baseline data were collected during the two-month pre-intervention assessment period. Intervention fidelity and process indicators were monitored during the five-month implementation phase. Post-intervention outcome assessment was conducted during the final three months of the project.

Statistical Analysis

Categorical variables were summarized using frequencies and percentages. Continuous variables were summarized using means with standard deviations or medians with interquartile ranges, depending on distribution. Pre- and post-intervention comparisons for categorical indicators were assessed using chi-square tests or Fisher's exact tests where appropriate. Continuous indicators were compared using t-tests or Mann–Whitney U tests, depending on data distribution.

Run charts and statistical process control charts were used to assess changes over time. A p-value of <0.05 was considered statistically significant. However, because this was a quality improvement study without a control group, clinical significance, absolute changes, and practical relevance were interpreted alongside p-values [12-15].

Ethical Considerations

This work was conducted as an institutionally supported quality improvement initiative at Kalkaal Hospital Cardiothoracic and Vascular Center. Hospital leadership and relevant clinical departments were aware of and contributed to the process. The initiative focused on improving routine perioperative systems and did not involve random allocation, experimental treatment, or withholding of standard care.

Patient-level data were obtained from routine clinical records and audit tools and were analyzed only in aggregate. No identifiable patient information was included in the manuscript. Access to data was limited to members of the quality improvement team. Staff feedback was collected confidentially and used only for quality improvement purposes. Participation in staff feedback activities was voluntary. The project was conducted in accordance with principles of confidentiality, patient safety, and health systems improvement.

Results

The results are summarized under three sections: FMEA risk identification, primary outcomes, and secondary outcomes. Figures 5–8 provide visual summaries of risk prioritization, intervention logic, implementation timeline, and overall improvement trends.

1. FMEA Risk Identification

Twenty-one potential failure modes were identified across the perioperative pathway. The five highest-priority risks were inadequate patient verification, delayed recognition of postoperative deterioration, equipment readiness failure, communication failure during handoff, and checklist noncompliance. Five failure modes were classified as the highest priority based on Risk Priority Number scoring, as shown in Table 1.

Table 1. High-Priority Failure Modes

Failure Mode	Severity	Occurrence	Detection	RPN
Inadequate Patient Verification	9	6	7	378
Delayed Recognition Of Postoperative Deterioration	9	5	8	360
Equipment Readiness Failure	10	5	6	300
Communication Failure During Handoff	7	6	7	294
Checklist Noncompliance	8	7	5	280

2. Primary Outcomes

Primary process and outcome indicators improved after implementation of the intervention bundle. Table 2 summarizes the main baseline and post-intervention results.

Table 2. Process Measures and Outcome Indicators

Indicator	Baseline	Post-intervention	Absolute Change	Relative Change	Interpretation
Checklist Compliance	72%	96%	+24 percentage points	33.3% relative increase	Clinically meaningful improvement in checklist reliability
Structured handoff compliance	61%	92%	+31 percentage points	50.8% relative increase	Improved communication reliability
Equipment delay events	10/month	6/month	−4/month	40% reduction	Fewer workflow disruptions
Median escalation time	42 min	18 min	−24 min	57.1% reduction	Faster response to deterioration
ICU readmissions	Observed events	0	Reduction	Not estimable without denominator	Interpret cautiously

Surgical Checklist Compliance

Checklist compliance increased from 72% at baseline to 96% after implementation of the cardiothoracic-adapted checklist. This improvement was statistically significant ($p < 0.01$). The run chart in Figure 2 demonstrates the improvement trend over time and shows that gains were sustained during the post-intervention evaluation period.

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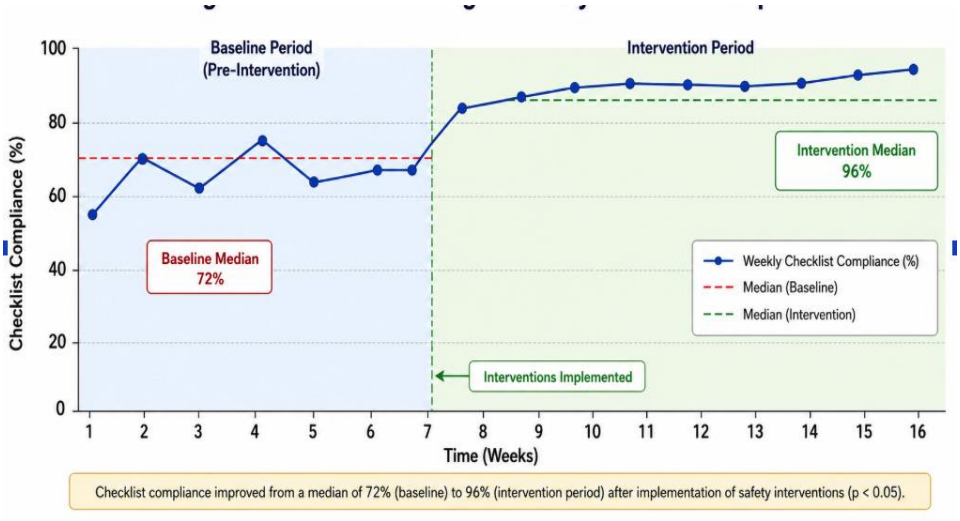


Figure 2. Run Chart - Surgical Safety Checklist Compliance

Equipment-related Delays

Equipment-related intraoperative delay events decreased from 10 per month to 6 per month, representing a 40% reduction. Mean delay duration decreased from 22 minutes to 8 minutes. The equipment readiness verification bundle contributed to the earlier detection of missing or malfunctioning items before patient transfer to the theatre. The statistical process control chart in Figure 3 shows the reduction in equipment failure-related delays after the introduction of the verification bundle.

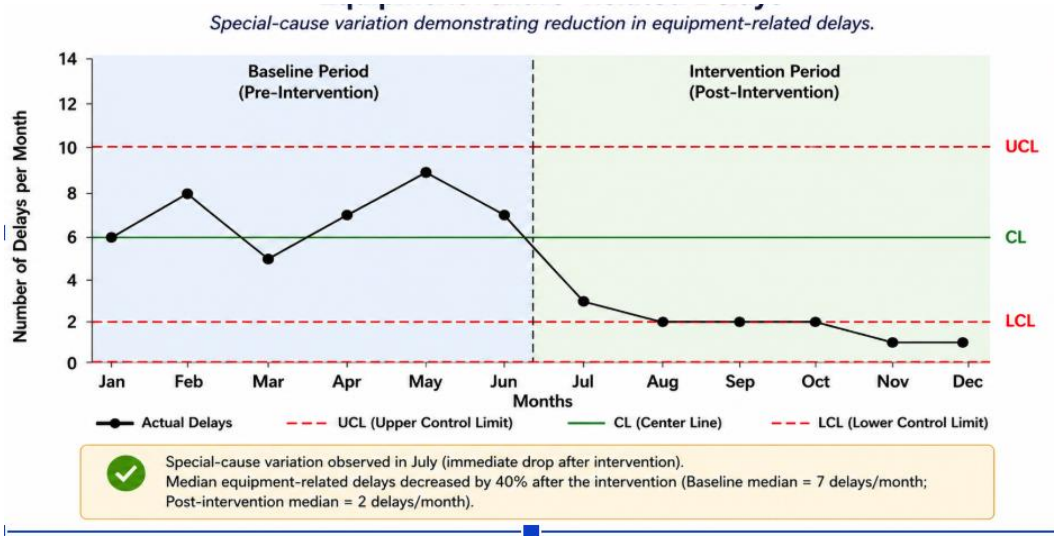


Figure 3. Statistical Process Control (SPC) Chart - Equipment Failure - Related Delays

ICU Readmissions

During the post-intervention observation period, ICU readmissions were eliminated. This improvement was associated with enhanced postoperative monitoring, structured escalation criteria, and more reliable handoff communication from theatre to ICU and from ICU to step-down care. The change was statistically significant ($p = 0.03$), although interpretation should consider the single-center design and limited observation period.

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Early Detection of Postoperative Deterioration

Median escalation time for deterioration improved from 42 minutes at baseline to 18 minutes post-intervention. Rapid escalation compliance improved substantially after the implementation of the ICU early warning escalation algorithm. The fishbone diagram in Figure 4 summarizes the major root causes contributing to surgical safety risks, including communication gaps, equipment readiness issues, unclear escalation pathways, documentation variation, and training needs.

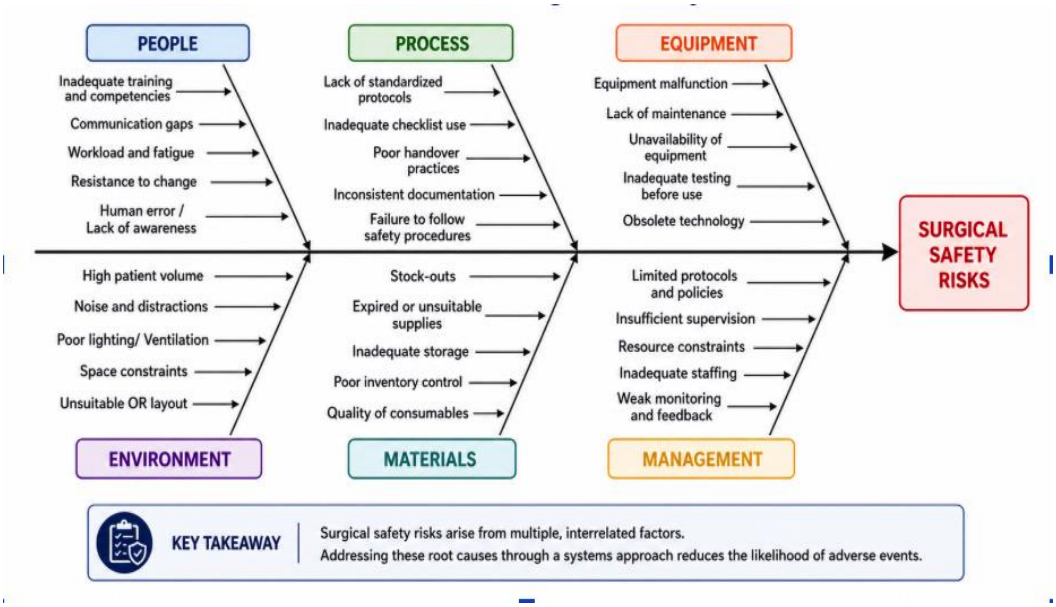


Figure 4. Fishbone (Ishikawa) Diagram - Root Causes of Surgical Safety Risk

Communication Reliability

Structured handoff adherence improved from 61% to 92%. Staff reported that the handoff tool reduced omissions, improved clarity of postoperative plans, and created a shared expectation regarding critical information transfer. Improvements were particularly noted for communication of intraoperative events, anticipated complications, drain and line status, medication infusions, and escalation triggers.

3. Secondary Outcomes

Staff-reported teamwork, confidence in reporting, and willingness to speak up improved after implementation. These findings suggest improvement in safety culture, although they should be interpreted cautiously because survey responses may be affected by social desirability and staff awareness of the intervention.

Safety Culture Improvement

Staff reporting confidence and perceptions of teamwork improved across survey domains. The FMEA risk priority matrix was used to visually classify risks according to severity and likelihood, helping the team prioritize interventions for the most critical hazards, as shown in Figure 5. Staff safety culture survey findings showed improvement in reporting confidence, perceived teamwork, and willingness to speak up about equipment or process concerns. While survey findings were not the primary outcome, they supported the interpretation that the intervention improved team reliability and psychological safety. The overall outcome dashboard is summarized in Figure 8.

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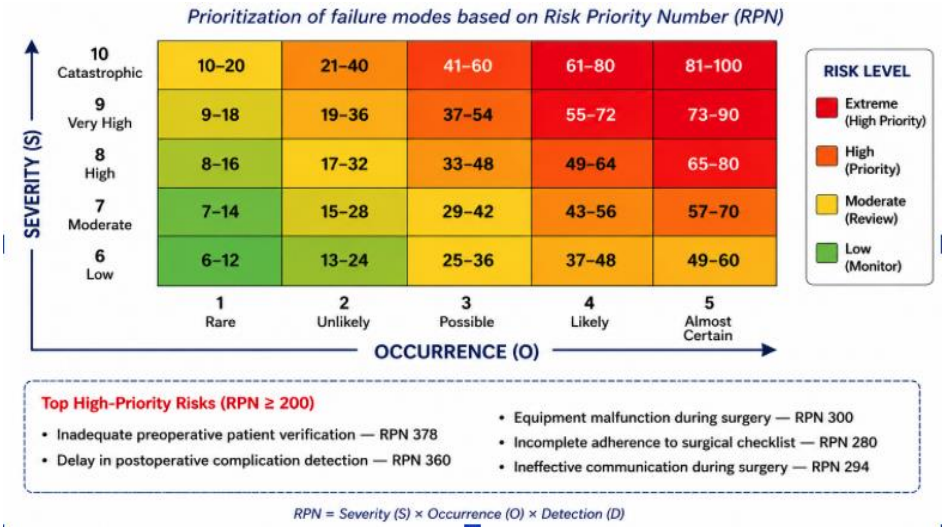


Figure 5. FMEA Risk Priority Matrix (Heat Map)

The intervention strategy was organized using a driver diagram that linked the project aim to primary drivers, secondary drivers, and specific change ideas, as presented in Figure 6.

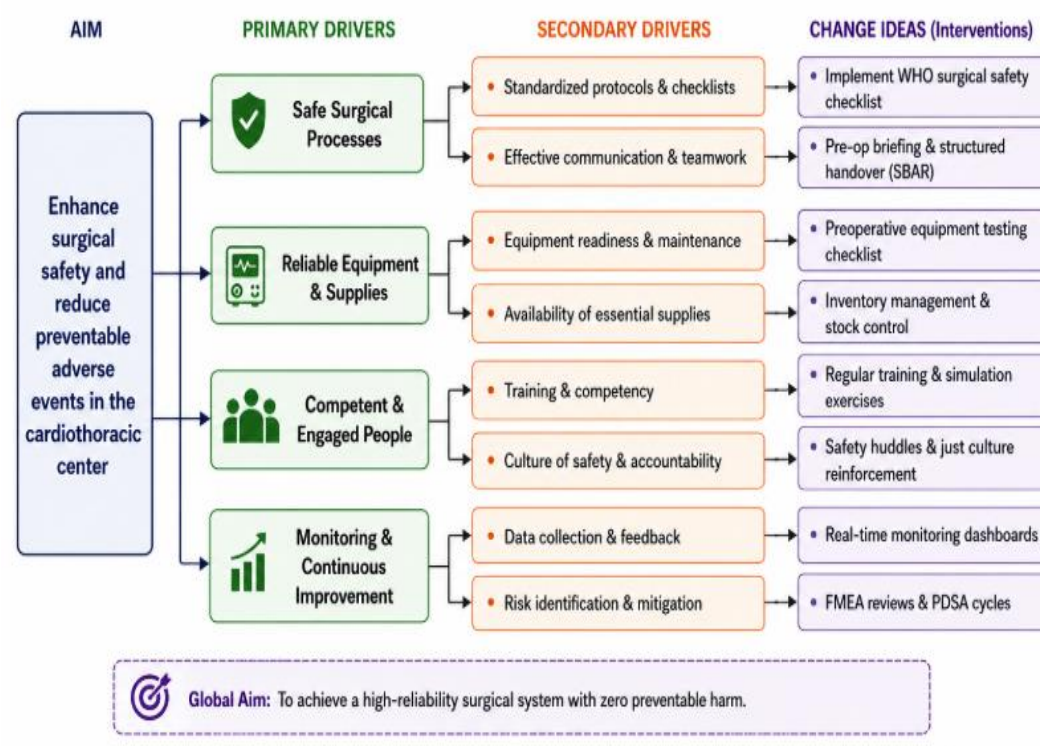


Figure 6. Driver Diagram for Surgical Safety Improvement

The 12-month project was implemented in four phases: baseline assessment, FMEA risk analysis, intervention implementation, and post-intervention evaluation. The sequence of activities is shown in Figure 7.

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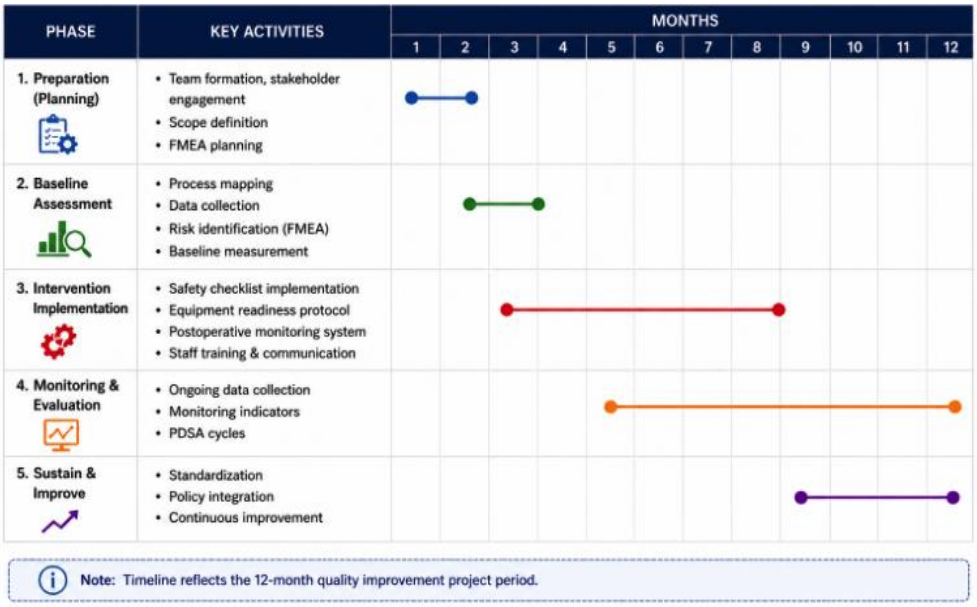


Figure 7. Quality Improvement Intervention Timeline

The overall outcome dashboard demonstrated improvements in checklist compliance, equipment readiness, structured handoff, escalation time, ICU readmissions, and safety culture indicators, as summarized in Figure 8.

INDICATOR	BASELINE (Pre-Intervention)	POST-INTERVENTION (12 Months)	CHANGE	P-VALUE	TREND
Surgical Safety Checklist Compliance	72%	96%	↑ 24 percentage points	< 0.05*	
Intraoperative Delays Due to Equipment Failure (median per month)	7 delays	2 delays	↓ 5 delays (40% reduction)	< 0.05*	
Wrong-site Surgery Risk (estimated)	Baseline risk (1.2 per 1,000 cases)	30% reduction in risk	↓ 30%	< 0.05*	
Postoperative Complication Detection (early identification)	Baseline system (average 48 hrs delay)	Real-time electronic monitoring in place (average 6 hrs delay)	System improvement	N/A	
ICU Readmissions (within 30 days)	Baseline rate (6.5%)	No ICU readmissions (0%)	100% elimination	N/A	

*Statistically significant improvement

N/A: Not applicable

Figure 8. Outcome Dashboard - Key Improvement

Discussion

The study found that an FMEA-guided surgical safety intervention bundle was associated with improvements in multiple perioperative safety indicators in a newly established cardiothoracic and vascular center in East Africa. The findings support the value of proactive risk assessment in high-risk surgical settings, particularly where services are new, workflows are evolving, and safety systems are still being formalized [16-19]. The improvement in surgical safety checklist compliance from 72%

to 96% is clinically meaningful. Contemporary evidence shows that surgical safety checklists can strengthen team communication, standardize safety-critical checks, and improve perioperative reliability when they are implemented as active communication tools rather than passive forms [3-5, 20, 21, 29, 30]. The findings are also consistent with recent evidence from Somalia showing that WHO Surgical Safety Checklist implementation is relevant but requires sustained training, monitoring, and institutional support in resource-limited hospitals [6].

The reduction in equipment-related delays from 10 to 6 events per month represents a 40% relative reduction. In cardiothoracic surgery, equipment readiness is a critical safety issue because missing or malfunctioning equipment can delay surgery, prolong anesthesia exposure, increase team stress, and create risk during critical phases of care. The equipment-readiness bundle helped move risk detection upstream, allowing problems to be identified before patients entered the operating theatre. This reflects human factors and high-reliability principles that hazards should be anticipated and controlled before they reach the patient [7-11, 22].

Structured handoff compliance improved from 61% to 92%. This is important because handoffs are known vulnerability points in complex care pathways. In cardiothoracic surgery, incomplete communication about intraoperative events, hemodynamic concerns, drains, lines, medications, blood products, and escalation triggers can delay recognition of postoperative complications. The structured handoff tool likely improved shared situational awareness and reduced dependence on memory [9, 20-23].

Median escalation time for postoperative deterioration improved from 42 minutes to 18 minutes. This 24-minute absolute reduction is clinically important because postoperative deterioration may progress rapidly in cardiothoracic patients. African surgical outcomes literature has emphasized the importance of postoperative surveillance and timely response to complications, particularly in settings with limited critical care resources [6, 28]. The early warning escalation algorithm addressed this risk by clarifying deterioration triggers, escalation timelines, and responsible responders.

However, improvements should be interpreted cautiously. The study used a pre–post design without a control group, and multiple interventions were implemented simultaneously. Therefore, the observed changes cannot be attributed to any single component of the bundle. Improvements may also have been influenced by staff learning over time, maturation of the newly established center, leadership attention, better documentation, or the Hawthorne effect. These limitations are common in pragmatic quality improvement work and should be transparently acknowledged [12-15, 27].

The intervention has practical implications for emerging specialty surgical centers in low-resource settings. First, safety systems should be designed early rather than added only after adverse events occur. Second, proactive risk assessment can help limited resources focus on the most serious and preventable hazards. Third, low-cost interventions such as checklists, handoff tools, huddles, and escalation algorithms can improve reliability when supported by training, audit, and leadership. Fourth, sustainability requires integration into routine documentation, staff orientation, audit cycles, incident learning systems, and organizational culture [1, 12, 20, 27].

Implications for Cardiothoracic Safety in Low-Resource Settings

This study has practical implications for emerging cardiothoracic centers in low-resource settings. Newly established specialist surgical services often develop rapidly in response to

unmet clinical need, but clinical expansion must be matched by deliberate investment in patient safety systems. The findings suggest that FMEA can help new cardiothoracic programs identify high-risk process failures early and design safer workflows before unsafe routines become normalized [16-19]. The intervention also demonstrates the value of low-cost safety tools. Locally adapted checklists, structured handoff forms, equipment-readiness checklists, early warning escalation algorithms, and daily safety huddles can improve reliability without requiring expensive digital infrastructure. These tools are especially useful in settings where staffing, equipment, documentation systems, and critical care capacity may be constrained [1, 3-6, 12, 22, 28].

Staff training is central to successful implementation. Surgical safety tools are unlikely to improve outcomes if staff view them as paperwork rather than communication and teamwork aids. Regular orientation, simulation-based practice, short refresher sessions, audit feedback, and multidisciplinary debriefings can strengthen shared situational awareness and support a culture where staff feel able to speak up about safety concerns [3-5, 20, 21].

Equipment readiness is particularly important in cardiothoracic surgery because procedures depend on functioning anesthesia equipment, monitors, suction, oxygen supply, warming devices, defibrillators, perfusion-related equipment where applicable, surgical instruments, implants, and backup systems. Assigning clear responsibility for equipment checks, involving biomedical engineering staff, documenting recurrent equipment problems, and reviewing these issues during safety huddles can reduce preventable delays and improve operative preparedness [7, 9, 22]. The approach is scalable because it relies on a transferable improvement method rather than a single fixed checklist. Other hospitals can adapt the same sequence: map the perioperative pathway, identify failure modes, score risk, prioritize high-severity hazards, implement locally feasible safeguards, and monitor indicators over time. However, spread should not mean copying the intervention without adaptation. Each center should adjust the tools to its case mix, staffing model, equipment availability, documentation system, and local safety culture [12-15, 27].

At policy level, the findings support the integration of proactive risk assessment into the development of new specialty surgical services. Hospital leaders, professional societies, ministries of health, and accreditation bodies can use FMEA-guided safety planning as part of cardiothoracic service readiness, surgical quality governance, incident learning systems, and national surgical safety strategies. Embedding these practices into policy may help ensure that expansion of specialized surgical access is accompanied by measurable improvements in safety, reliability, and accountability [1, 25, 26, 29, 30].

Sustainability and Spread

Sustainability requires embedding the interventions into routine operations. For example, checklist completion should be audited regularly, equipment readiness checks should be assigned to named roles, handoff tools should be included in clinical records, and escalation algorithms should be reinforced during ICU orientation. Safety huddles and debriefings should remain short, practical, and action-oriented so that staff perceive them as useful rather than burdensome.

Spread to other settings would require local adaptation. Hospitals with different staffing models, equipment availability, case mix, and documentation systems may need to modify the scoring thresholds and intervention bundle. Nevertheless, the core method—mapping the process, identifying failures, scoring risks,

prioritizing interventions, measuring outcomes, and learning from results—is transferable.

Limitations

This study has several limitations. First, it was conducted in a single newly established cardiothoracic center, which may limit generalizability to other hospitals with different staffing, resources, case mix, or organizational maturity. Second, the pre–post design without a control group limits causal inference. Observed improvements may have been influenced by the Hawthorne effect, increased staff familiarity with workflows, leadership attention, improved documentation, or other concurrent changes. Third, the intervention was implemented as a bundle, so the independent effect of each component cannot be determined. Fourth, the sample size was pragmatic, and no formal power calculation was conducted. The study may therefore have been underpowered to detect changes in rare clinical outcomes such as mortality, major complications, or ICU readmission. Fifth, some indicators depended on documentation quality, which may have improved during the project and influenced measured compliance. Finally, the post-intervention observation period was relatively short, and longer follow-up is needed to assess sustainability.

Future Directions

Future work should explore multicenter replication across cardiothoracic and other high-risk surgical centers in East Africa. Longer-term evaluation should assess whether improvements in checklist compliance, equipment readiness, handoff quality, escalation time, and ICU readmissions are sustained beyond the initial implementation period. Future studies could also integrate FMEA with digital monitoring tools, electronic incident reporting, predictive analytics for postoperative deterioration, simulation-based team training, and human factors evaluation [20, 22-24]. Cost-effectiveness analysis would be useful to quantify the economic value of reduced delays, fewer readmissions, and improved safety outcomes.

Conclusion

This prospective single-center quality improvement study found that an FMEA-guided surgical safety intervention bundle was associated with improved perioperative safety indicators in a newly established cardiothoracic and vascular center in East Africa. Improvements were observed in checklist compliance, equipment-related delays, structured handoff compliance, escalation time for postoperative deterioration, ICU readmissions, and staff safety-culture indicators. The findings suggest that proactive risk assessment, multidisciplinary ownership, locally adapted checklists, equipment-readiness processes, structured handoff, early warning escalation, and safety huddles can strengthen surgical reliability in resource-constrained specialty settings [1, 3-5, 7-9, 16-22]. However, because the study used a pre–post design without a control group and implemented multiple interventions simultaneously, conclusions about causality should be cautious [12-15, 27].

FMEA appears to be a practical and scalable framework for embedding patient safety into the early development of complex surgical services. Future multicenter studies with longer follow-up, stronger comparative designs, cost analysis, patient-level outcome evaluation, and sustainability assessment are needed to confirm broader impact [25-27].

Data Availability

The aggregated quality improvement data supporting the findings of this study are available from the corresponding author upon reasonable request and subject to institutional approval.

Individual patient-level data are not publicly available because of confidentiality requirements and institutional data protection policies. No identifiable patient information was used in the study.

Funding

This quality improvement research study did not receive specific external funding from public, commercial, or not-for-profit funding agencies. The project was implemented using institutional quality improvement resources and the routine participation of clinical and quality teams at Kalkaal Hospital Cardiothoracic and Vascular Center.

Conflict of Interest

The authors declare no conflict of interest.

Ethical Approval

The study was conducted as a quality improvement research initiative with institutional approval from the participating cardiothoracic center. Patient confidentiality was maintained throughout. No identifiable patient data were used. Ethical principles aligned with institutional and international standards for health systems improvement research.

Author Contributions

Juliet conceptualized the study, led the quality improvement design, contributed to methodology, analysis, interpretation, manuscript drafting, and final approval. All authors contributed to implementation support, critical revisions, and approval of the final manuscript.

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Artificial Intelligence in Healthcare: A Narrative Review of Recent Clinical Applications, Implementation Strategies and Challenges in Zambia

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Abstract *Artificial intelligence (AI) is rapidly transforming healthcare delivery globally, offering significant potential to address critical health system challenges. The study employed a narrative literature review design guided by the narrative synthesis framework. with literature sourced from peer-reviewed databases and grey literature published between 2019 and 2026. A total of 68 publications met the inclusion criteria and were retained for synthesis. The review revealed that AI has been applied across diagnostic imaging, clinical decision support, public health surveillance, and telemedicine. Zambian studies have evaluated AI for tuberculosis diagnosis, breast cancer detection, and occupational lung disease. Implementation strategies emphasised governance, infrastructure, partnerships, and capacity building. Zambia has made notable progress through its National AI Strategy, SmartCare Pro initiative consolidating over 12 million patient records, Digital Health Data Governance Framework partnership with Finland, and Health AI Global Regulatory Network membership. However, significant challenges persist including unreliable infrastructure, nascent regulatory frameworks, workforce gaps, algorithmic bias, and financial constraints. Despite persistent challenges, substantial opportunities exist for AI to strengthen health service delivery, expand access to quality care, enhance efficiency, strengthen surveillance, and foster local innovation in Zambia. The National Telemedicine and AI Health Diagnostics Pilot and local innovations such as Larry RX AI demonstrate AI's potential. Recommendations include accelerating National AI Strategy operationalisation, developing a comprehensive regulatory framework, investing in resilient infrastructure, scaling workforce development, establishing sustainable financing, and aligning with continental frameworks.*

Keywords *Artificial Intelligence, Challenges, Clinical Applications, Digital Health, Healthcare, Implementation Strategies, Narrative Review, Zambia.*

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Introduction

Artificial intelligence (AI) has emerged as one of the most transformative technologies in modern healthcare, fundamentally changing the way diseases are diagnosed, treated, monitored, and prevented. AI refers to the ability of computer systems to perform tasks that traditionally require human intelligence, including learning from data, recognizing patterns, making predictions, understanding language, and supporting decision-making. In healthcare, AI technologies such as machine learning (ML), deep learning (DL), natural language processing (NLP), computer vision, and generative AI are increasingly being integrated into clinical workflows to improve diagnostic accuracy, optimize treatment planning, enhance administrative efficiency, and strengthen public health surveillance [1].

Globally, AI applications have expanded across nearly every area of clinical medicine. In diagnostic imaging, deep learning algorithms have achieved levels of accuracy comparable to expert radiologists in detecting conditions such as breast cancer, tuberculosis, diabetic retinopathy, pneumonia, and stroke from radiological images. AI-supported clinical decision support systems assist physicians by analysing laboratory results, patient histories, and clinical guidelines to recommend personalized treatment options. Furthermore, AI-powered predictive analytics enables healthcare providers to identify patients at high risk of deterioration, hospital readmission, or chronic disease complications, thereby facilitating preventive interventions. During infectious disease outbreaks, AI has also been used to strengthen epidemiological surveillance, disease forecasting, and contact tracing, demonstrating its value in supporting resilient healthcare systems [2].

The global COVID-19 pandemic significantly accelerated AI adoption in healthcare by exposing weaknesses in conventional healthcare delivery systems. AI tools were deployed to assist in outbreak prediction, vaccine development, medical image interpretation, clinical triage, telemedicine, and public health surveillance.

Most AI healthcare research, development, and implementation have occurred in North America, Europe, and parts of Asia, where strong digital infrastructure, comprehensive health information systems, substantial financial resources, and well-established regulatory frameworks support innovation. Conversely, many African countries continue to experience challenges related to limited digital infrastructure, inadequate internet connectivity, shortages of skilled AI professionals, fragmented health information systems, insufficient regulatory oversight, poor data quality, and financial constraints that limit large-scale AI adoption [3, 4].

Nevertheless, AI presents considerable opportunities for strengthening healthcare delivery in resource-constrained settings. In many LMICs, shortages of healthcare workers, limited specialist availability, and geographical barriers reduce access to quality healthcare services, particularly in rural areas. AI-supported telemedicine, automated diagnostic systems, mobile health applications, and decision support systems can help bridge these gaps by expanding access to specialized care while improving efficiency [5].

Within Africa, digital health transformation has accelerated over the past decade through investments in electronic medical records, health information systems, telemedicine, and mobile health technologies. AI is increasingly viewed as the next phase of this digital transformation. Several African countries have begun exploring AI for disease surveillance, maternal and child health, pathology, radiology, and predictive analytics [6].

In Zambia, the healthcare system continues to face significant challenges, including shortages of skilled healthcare personnel, unequal distribution of healthcare services between urban and rural areas, increasing burdens of communicable and non-

communicable diseases, limited specialist services, and resource constraints. These challenges have intensified the need for innovative technologies capable of improving healthcare delivery and expanding access to quality services. Recognizing the importance of digital transformation, the Government of Zambia has prioritized digital health through the Ministry of Health's Digital Health Strategy 2022–2026, which seeks to strengthen health information systems, improve interoperability, promote electronic health records, enhance digital governance, and establish an integrated digital health ecosystem capable of supporting advanced technologies such as AI.

The implementation of Zambia's Digital Health Strategy represents an important foundation for future AI adoption because AI systems depend heavily on reliable digital infrastructure, interoperable information systems, standardized health data, and effective governance mechanisms [7]. The strategy aligns with broader national efforts to improve healthcare quality, strengthen disease surveillance, enhance service delivery, and accelerate progress toward Universal Health Coverage through digital innovation. While AI is not yet widely deployed across Zambia's healthcare facilities, the country's increasing investment in digital health infrastructure creates opportunities for future integration of AI into clinical practice, health management, and public health programmes.

Recent developments further indicate Zambia's growing interest in AI governance and digital innovation. Alongside broader digital transformation initiatives, policymakers have begun exploring national AI policy and regulatory frameworks to guide the responsible adoption of AI across sectors, including healthcare. Such initiatives recognize that successful AI implementation requires not only technological investment but also appropriate legislation, ethical governance, workforce development, cybersecurity, and protection of patient privacy.

Given the rapid evolution of AI technologies and Zambia's ongoing digital health transformation, there is a need to consolidate current evidence to better understand how AI can contribute to strengthening healthcare delivery within the Zambian context. A narrative review provides an appropriate methodological approach for synthesizing diverse evidence from peer-reviewed literature, policy documents, and implementation reports to identify recent clinical applications, implementation strategies, opportunities, and challenges. Such evidence can inform policymakers, healthcare professionals, researchers, technology developers, and healthcare institutions in designing contextually appropriate AI implementation frameworks that promote equitable, ethical, and sustainable adoption of AI within Zambia's healthcare system [6].

Therefore, a narrative review is necessary to synthesize recent evidence on AI in healthcare, identify implementation strategies and challenges, and provide context-specific insights that can guide future research, policy formulation, and responsible AI adoption in Zambia [8-10].

The specific objectives are:

1. To determine the clinical applications of artificial intelligence in healthcare, focusing on diagnostic imaging, clinical decision support, public health surveillance, and telemedicine.
2. To examine the strategies used to implement artificial intelligence in healthcare in Zambia, including governance, infrastructure, stakeholder involvement, and capacity building.
3. To identify the major technological, infrastructural, regulatory, ethical, and financial challenges affecting the adoption of artificial intelligence in Zambia’s healthcare system.
4. To explore the opportunities and future prospects of artificial intelligence for

improving healthcare delivery in Zambia.

Materials and Methods

Description of the Site

The study was carried out in Zambia focusing on various AI in health care studies that were done from 2019–2026.

Description of the Experiments Done

The study adopted a narrative literature review design. The narrative review design was considered appropriate because the study sought to examine recent clinical applications of artificial intelligence (AI), implementation strategies, challenges, and future opportunities within the healthcare sector, particularly in Zambia. The study was underpinned by the interpretivist research philosophy.

Description of the Laboratory Methods

The study adopted a qualitative and inductive research approach. Literature was obtained from both peer-reviewed and grey literature sources to ensure comprehensive coverage of current evidence.

A comprehensive literature search was conducted using Boolean operators (AND, OR) and Medical Subject Headings (MeSH) where applicable. Searches were limited to publications between 2019 and 2026 to capture recent developments in AI healthcare applications.

The study included English-language studies published between 2019 and 2026 that examined AI applications in healthcare, particularly in Zambia and Southern Africa, including quantitative, qualitative, mixed-methods and review studies, as well as peer-reviewed articles and recognised institutional reports. Studies were excluded if they were published before 2019, in languages other than English, focused on AI outside healthcare, lacked empirical or analytical evidence, were duplicates, unavailable in full text, or did not address AI implementation or adoption in healthcare.

The screening process followed four stages adapted from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Description of Analysis Methods Used

The study employed the Narrative Synthesis Framework proposed by Popay et al [8]. Narrative synthesis is appropriate where evidence originates from diverse methodologies and contexts, making statistical meta-analysis inappropriate.

Results

Summary of Reviewed Literature

The reviewed literature covered a wide range of clinical domains. Diagnostic imaging was the most extensively represented domain, with studies on AI applications in radiology, pathology, dermatology, and ophthalmology.

Table 1 shows the Key Zambian AI Studies and Initiatives carried out from 2019–2026.

Table 1. Key Zambian AI Studies and Initiatives (2019–2026)

Study/Initiative	Year	Focus	Key Findings/Outcomes
InferRead DR Chest Evaluation for TB Screening (Somwe et al., 2025)	2025	Diagnostic performance of CAD for TB in adults	AUC 0.81 (95% CI: 0.78-0.83); acceptable performance in high HIV/TB burden setting; additional training recommended
CAD for TB Diagnosis in Children (Muyoyeta et al., 2025)	2025	Diagnostic accuracy of CAD systems for paediatric TB	CAD4TB_v7 and qXR_v4 achieved AUCs of 0.75 and 0.69 against microbiological reference; accuracy improved against expert reader reference (AUCs 0.81 and 0.83)

Thermalytix Breast Cancer Detection (Mwale et al., 2025)	2025	AI-enhanced breast thermal imaging	Strong correlation with mammography; potential as additional tool for early detection in Zambia
CAD4Silicosis and CAD Spirometry (Zambart, 2025)	2025	AI tools for occupational lung disease	WHO-endorsed CAD4Silicosis; world's first tool predicting lung function from chest X-ray; real-world validation study underway
National Telemedicine and AI Health Diagnostics Pilot (TechAfrica News, 2025)	2024-2025	AI-supported remote diagnostics	Expanded to 20 health facilities in 2025; integrates remote diagnostics, AI-supported clinical analysis, enhanced connectivity for rural clinics
National AI Strategy 2024-2026 (OECD, 2026)	2024	National framework for AI adoption	Positions Zambia for AI-driven economic growth; six priority sectors including healthcare; National AI Council established
SmartCare Pro Initiative (ITWeb Africa, 2026)	2014–present	Electronic health records	Consolidated >12 million patient records; over 2,000 health facilities connected; >14,000 health workers trained; foundation for AI-ready healthcare system
Digital Health Data Governance Framework (CIDRZ, 2024)	2024	Health data governance	First-ever framework for Ministry of Health; co-developed with CIDRZ
Health Informatics Programmes at UNZA (CIDRZ, 2024)	2024–2025	Health informatics education	Undergraduate and postgraduate programmes established; health informatics competency framework developed

Source: *Field data (2026)*

Table 2. Clinical Applications of AI in Healthcare

Author/s	**Findings**
Muyoyeta et al. (2025)	AI-based CAD tools showed potential for paediatric TB diagnosis in Lusaka. CAD4TB_v7 and qXR_v4 achieved AUCs of 0.75 and 0.69 against microbiological standards, improving to 0.81 and 0.83 against expert-reader standards. Further training using paediatric images was recommended.
TechAfrica News (2025); ITWeb Africa (2025)	Zambia's National Telemedicine and AI Health Diagnostics Pilot, launched in 2024 and expanded to 20 health facilities in 2025, demonstrates growing use of AI-supported clinical analysis to improve healthcare access, particularly in rural areas.

Global Fund (2024); Somwe et al. (2025); Muyoyeta et al. (2025)	Zambia's electronic health records and integrated disease surveillance systems provide opportunities for AI-supported disease prediction, early intervention and public health surveillance, particularly for TB and HIV. However, data sparsity and limited analytical capacity remain barriers to adoption.
Ministry of Technology and Science (2025)	Larry RX AI, a Zambian-developed tool, supports medication safety by analysing drug–drug interactions and compliance. Pilot implementation across 20 health posts in 10 provinces demonstrates emerging local capacity for AI-driven clinical decision support.

Source: *Field data (2026)*

The literature in Table 2 indicates that AI has significant potential to strengthen healthcare delivery in Zambia, particularly in diagnosis, telemedicine, disease surveillance and medication safety. Muyoyeta [10] demonstrate that AI-based diagnostic tools can support paediatric TB detection, although further local training is required to improve accuracy. The expansion of the National Telemedicine and AI Health Diagnostics Pilot shows that AI can help extend specialised healthcare services to rural and underserved populations. Zambia's electronic health records also provide an important foundation for AI-supported disease prediction and surveillance, although poor data quality and limited analytical capacity remain major barriers. Finally, the development of Larry RX AI demonstrates growing local capacity to develop AI solutions for medication safety.

Table 3. Implementation Strategies

Author/s	**Findings**
OECD (2026)	Zambia's National Artificial Intelligence Strategy (2024–2026) provides a framework for using AI to promote economic growth, improve public services and support inclusive development. However, Zambia's AI ecosystem remains at an early stage, facing limited digital infrastructure, shortages of skilled AI professionals, fragmented data systems and inadequate dedicated AI governance frameworks.
ITWeb Africa (2026)	The SmartCare Pro initiative has consolidated more than 12 million patient records into a unified electronic health records system. More than 2,000 health facilities have been connected and over 14,000 health workers trained, providing an important foundation for AI-enabled healthcare and data-driven decision-making.
CIDRZ (2024)	CIDRZ, in partnership with the Ministry of Health, developed Zambia's first Digital Health Data Governance Framework. It also supported a health informatics competency framework and the development of health informatics programmes at the University of Zambia. These initiatives strengthen data governance, workforce capacity and digital health implementation.

TechAfrica News (2025)	Zambia's National Telemedicine and AI Health Diagnostics Pilot, launched in 2024 and expanded to 20 health facilities in 2025, integrates remote diagnostics, AI-supported clinical analysis and improved connectivity. The initiative particularly aims to expand access to quality healthcare in rural areas and support decentralisation of healthcare services.

Source: *Field data (2026)*

Table 3 shows that Zambia is establishing important foundations for the adoption of AI in healthcare, but significant gaps remain. The National AI Strategy provides policy direction, while SmartCare Pro has strengthened the country's digital health infrastructure by consolidating patient records and connecting health facilities. CIDRZ has further contributed through data governance and health informatics capacity development, which are essential for effective and responsible AI use. The expansion of the National Telemedicine and AI Health Diagnostics Pilot also demonstrates the potential of AI to decentralise healthcare and improve access in rural areas.

Table 4. Challenges Affecting AI Adoption

Author/s	**Findings**
Owoyemi et al. (2024)	AI research in low- and middle-income countries is largely focused on AI model development, with limited evidence of external validation and actual clinical deployment. In Zambia, shortages of skilled healthcare workers and under-resourced facilities further constrain AI adoption.
Muyoyeta et al. (2025)	The paediatric TB CAD study in Lusaka found that AI diagnostic tools may require additional training using paediatric images to improve performance. The paucibacillary nature of TB in children may also make comparison with expert readings more appropriate.
Global Fund (2024)	Zambia's dependence on hydropower (83% of installed generation capacity) exposes health facilities to power disruptions. Droughts have also affected electricity, internet connectivity and telecommunications, creating significant infrastructure barriers to AI adoption. Solar power and internet support for 650 priority facilities are helping address these challenges.
OECD (2026)	Zambia has established a national AI strategy, but AI healthcare regulation and governance remain at an early stage. The strategy promotes ethical and responsible AI through policy and regulatory frameworks, but practical implementation of safeguards is still developing.

Source: *Field data (2026)*

Table 4 highlights that AI adoption in Zambia's healthcare system faces several interconnected challenges. Limited skilled personnel and under-resourced health facilities restrict the capacity to develop, validate and deploy AI technologies. The need for further training of AI diagnostic tools also shows that local validation is essential to ensure accuracy

for Zambian populations. In addition, unreliable electricity, internet connectivity and telecommunications create major infrastructure barriers, particularly in rural areas. Although Zambia has established a National AI Strategy, regulatory and ethical governance mechanisms are still developing. Overall, successful AI adoption will require investment in infrastructure, workforce skills, local validation, data systems and effective regulation.

Table 5. Opportunities and Future Prospects

Author/s	Findings
Somwe et al. (2025); Muyoyeta et al. (2025)	AI-enhanced point-of-care diagnostics can help address diagnostic gaps, improve accuracy among non-specialist healthcare workers, and provide quality assurance at scale, particularly in under-resourced settings.
Alowais et al. (2024)	The widespread use of ChatGPT among pharmacy students in Zambia indicates growing AI literacy and acceptance among future healthcare professionals, creating opportunities for wider adoption of AI technologies in healthcare.
CIDRZ (2024)	CIDRZ and the Ministry of Health developed Zambia's Digital Health Data Governance Framework and supported health informatics programmes at UNZA. These initiatives strengthen data governance, digital skills and local capacity necessary for AI innovation in healthcare.

Source: *Field data (2026)*

The table 5 indicates that Zambia has significant opportunities to leverage AI to strengthen healthcare delivery and build local capacity. AI-supported diagnostics can help address shortages of specialists by assisting non-specialist healthcare workers and improving the quality of diagnosis. The growing use of AI tools such as ChatGPT among pharmacy students suggests increasing AI literacy and acceptance among future healthcare professionals. Furthermore, the Digital Health Data Governance Framework and health informatics programmes supported by CIDRZ and the Ministry of Health are strengthening data governance, digital skills and institutional capacity.

Discussion

Recent evidence shows that AI is increasingly being applied to clinical diagnosis and disease surveillance in Zambia, particularly in diagnostic imaging. Studies in Lusaka demonstrate that computer-aided diagnosis (CAD) tools can support tuberculosis detection among both children and adults, although further training and local validation are required to improve performance across different patient groups [10, 17]. AI-enhanced technologies such as Thermalytix also show potential for early breast cancer detection, while CAD4Silicosis and CAD Spirometry offer promising applications for occupational lung disease among Zambia’s mining population [11]. In addition, Zambia’s electronic health records and disease surveillance systems provide opportunities for AI-driven prediction and early intervention for diseases such as TB and HIV, although data sparsity and limited analytical capacity remain significant barriers to implementation [10, 15, 17].

The literature shows that Zambia is developing a multi-level implementation framework for AI in healthcare, supported by the National AI Strategy (2024–2026), which emphasises ethical governance, human-capital development, digital infrastructure, data

systems, research, innovation and multi-stakeholder collaboration (OECD, 2026). These efforts are reinforced by the Zambia Digital Health Strategy (2022–2026), the Digital Health Data Governance Framework, health informatics training programmes and the expansion of SmartCare Pro, which has consolidated over 12 million patient records and connected more than 2,000 health facilities [13, 28]. Infrastructure and capacity-building are further supported through Global Fund investments in connectivity, solar power, digital equipment and workforce training, while partnerships with Finland, the World Bank and other international organisations provide technical and financial assistance for AI and digital health development [15, 20]. At the clinical level, the expansion of the Telemedicine and AI Health Diagnostics Pilot and introduction of AI technologies for occupational health demonstrate practical efforts to integrate AI into service delivery and generate local evidence [12]. Overall, Zambia's implementation strategy combines policy and governance, digital infrastructure, data integration, workforce development, international partnerships and local validation, although persistent challenges such as unreliable electricity, limited technical skills, fragmented systems and emerging AI governance requirements may constrain large-scale adoption [14, 15, 18].

The literature identifies infrastructural, technical, regulatory, ethical, human-resource and financial challenges as major barriers to AI adoption in Zambia. Under-resourced health facilities and shortages of skilled healthcare workers limit the capacity to implement and sustain AI, while limited external validation and clinical deployment of AI models in low- and middle-income countries raise concerns about their applicability to local populations [17]. Data sparsity, poor quality and limited interpretability of machine-learning models further constrain the effective use of electronic health records for AI-supported decision-making [11, 12]. In addition, Zambia's dependence on hydropower makes healthcare facilities vulnerable to power outages and disruptions to internet and telecommunications, particularly during droughts [15]. Although the country has developed a National AI Strategy and emerging regulatory guidelines, AI governance, accountability and ethical oversight remain at an early stage [14]. Concerns regarding data privacy, algorithmic bias, inclusion and potential job displacement also require stronger safeguards, while limited domestic financing and competing health priorities make long-term investment in AI infrastructure, maintenance, training and system updates difficult despite support from organisations such as the Global Fund and World Bank [15, 22].

The literature indicates that Zambia has significant opportunities to leverage AI to strengthen healthcare delivery, improve access and enhance health-system efficiency. AI-supported point-of-care diagnostics can improve the accuracy of diagnosis, particularly where specialist healthcare workers are scarce, while telemedicine and AI-enabled clinical analysis can extend specialised services to rural and underserved communities [21]. Expanding fibre-optic and satellite connectivity further creates opportunities for remote healthcare and digital service delivery [16]. AI also has potential to improve pharmaceutical supply chains, reduce costs and enhance medication safety, as demonstrated by the locally developed Larry RX AI for identifying drug interactions [18]. Furthermore, Zambia's National AI Strategy, SmartCare Pro, digital health investments, and emerging regulatory frameworks provide an enabling policy and technological foundation for responsible AI adoption [19]. Membership in the Health AI Global Regulatory Network also provides access to international expertise and collaboration [21]. Overall, Zambia is making progress towards AI readiness, but continued investment in infrastructure, human capacity,

data systems, governance and local research will be essential to realise the full benefits of AI in healthcare.

Conclusion

The narrative review concludes that AI has considerable potential to strengthen healthcare delivery in Zambia, particularly through computer-aided diagnosis, telemedicine, disease surveillance, medication safety and occupational health applications. Initiatives such as the National AI Strategy, SmartCare Pro, the Digital Health Data Governance Framework and international partnerships provide an important foundation for responsible AI adoption. However, the benefits of AI remain constrained by inadequate infrastructure, unreliable electricity and internet connectivity, poor data quality, limited technical and analytical skills, emerging regulatory frameworks and financial limitations. Although locally developed innovations and AI validation studies demonstrate growing capacity, the limited amount of Zambia-specific empirical evidence highlights the need for greater local validation, investment in infrastructure and human capacity, stronger governance, sustainable financing and inclusive implementation to ensure that AI produces equitable and sustainable improvements in healthcare outcomes.

Conflict of Interest

None declared.

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Ethics

Professionalism was upheld in carrying out the research.

Data Availability

The grey literature that was examined in the course of this study can be obtained from the corresponding author upon a reasonable request.

Author Contributions

The author made most of contribution to the development, conceptualization, analysis, and composition of this paper. A research assistant was engaged in data cleaning and proofreading.

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Exploring Emotional Intimacy, Grief, and Family Dynamics in Octogenarians: Implications for Redefining Geriatric Care

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Abstract *The global population of octogenarians is rising rapidly, posing significant challenges for geriatric care. This study applies a neuropsychosocial perspective, integrating geriatric psychiatry, neurobiology, social psychology, and elder law, to review literature on emotional vitality, grief, sexuality, and boundary concerns in octogenarians. Findings show that companionship, intimacy, and family engagement remain central to well-being but are often disrupted by bereavement, loneliness, and social isolation. Contrary to common assumptions, aging does not eliminate sexual expression. However, this creates a dual reality: in which certain older adults face risks of exploitation, whereas others, especially older men, may transgress relational boundaries. Current care frameworks focus mainly on preventing neglect and abuse, yet inadequately address sexuality and relational well-being. A shift toward holistic geriatric care is needed, emphasizing dignity, emotional vitality, structured grief counseling, intimacy-focused interventions, caregiver training, and family education to reduce psychological distress and improve quality of life among octogenarians.*

Keywords *Emotional Intimacy, Grief, Geriatric Care Reform, Family Dynamics, Octogenarians, Sexuality in Aging.*

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Introduction

Octogenarians, defined as individuals aged 80–89 years, represent one of the most rapidly expanding segments of the global population [1, 2]. Advances in healthcare, nutrition, and disease prevention have significantly extended life expectancy, resulting in demographic shifts with profound clinical and societal implications. While aging in this cohort has traditionally been perceived primarily through the lens of physical decline, many octogenarians continue to lead emotionally fulfilling lives, maintain meaningful social roles, and express ongoing needs for intimacy and connection [3]. A comprehensive understanding of this population therefore requires a multidimensional approach that transcends the biomedical model, incorporating psychological, relational, and ethical dimensions into the care and study of older adults.

Recent advances in vaccination, nutrition, and chronic disease management have been especially influential in shaping the longevity of octogenarians. As a result, the population of individuals aged 80 years and older is expanding rapidly. The United Nations projects that by 2050, this group will exceed 71 million globally, with particularly high growth expected in developing countries such as India and China [4]. Demographic trends further indicate that by 2030, one in six individuals worldwide will be aged 60 years or older. The number of older adults is expected to rise from 1 billion in 2020 to 1.4 billion in 2030, and to 2.1 billion by 2050 [5]. Within this broader demographic, those aged 80 years and above are projected to triple, reaching approximately 426 million by mid-century.

While these demographic changes signify remarkable achievements in global public health, they also present challenges that extend well beyond physical health and disease management. The psychological, emotional, and social dimensions of aging, particularly among octogenarians, remain insufficiently explored and inadequately addressed in clinical practice. Conventional geriatric care frameworks frequently emphasize biomedical concerns such as chronic illness, fall prevention, and cognitive decline [3, 4]. Although these aspects are essential, such an approach risks marginalizing the equally significant emotional and relational aspects of aging, which are critical to overall well-being.

Contrary to prevailing assumptions that intimacy and emotional needs diminish with age, emerging evidence demonstrates that older adults often sustain, and in some cases intensify, their desires for companionship, closeness, affectionate touch, and sexual expression during the ninth and tenth decades of life [6]. These affective needs are not peripheral but central, contributing directly to psychological health, resilience, and life satisfaction. Their neglect may result in loneliness, grief-related morbidity, and relational disconnection.

This article seeks to illuminate the emotional and relational dimensions of aging in octogenarians. Drawing on neurobiological, psychosocial, and interpersonal perspectives, it examines mood regulation, intimacy in late life, grief processing, shifting family dynamics, and emotional resilience. In doing so, it highlights critical gaps in current geriatric care models and advocates for integrative, ethically informed approaches. A holistic framework of care must recognize that fundamental human needs for love, connection, and meaning do not diminish with age; rather, they often deepen, requiring sustained clinical, familial, and societal attention.

Neurobiological Basis of Emotional Continuity in Aging

As people age, certain cognitive abilities such as episodic memory, attention, processing speed, and executive function typically decline. However, emotional regulation often

remains stable and may even improve in older adults. This observation is explained by socioemotional selectivity theory, which posits that older individuals prioritize positive and emotionally meaningful experiences, thereby sustaining well-being in later life [7].

The well-being of octogenarians extends beyond medical care, encompassing emotional, psychological, and social dimensions. As illustrated in Figure 1, four interrelated domains, emotional intimacy, grief, family dynamics, and neuropsychosocial resilience, are central to quality of life in later years. Emotional intimacy reflects companionship and romantic or sexual expression. Grief represents the effects of bereavement, loneliness, and adaptation to loss. Family dynamics emphasize shifting caregiving roles and the importance of intergenerational ties. Neuropsychosocial resilience highlights mood regulation and cognitive engagement, both essential for maintaining purpose and adaptability in advanced age.



Figure 1. Key Domains of Octogenarian Well-being for Redefining Elderly Care

From a neurobiological perspective, aging affects several neurotransmitter systems. A decline in dopamine is associated with reduced motivation to seek new experiences, including romantic or sexual ones [8]. Altered serotonin regulation increases vulnerability to depression and anxiety [9]. Additionally, shrinkage of the prefrontal cortex impairs impulse control, sometimes resulting in heightened emotional reactivity or disinhibition [10].

Importantly, brain regions involved in emotional memory, such as the amygdala, remain relatively active compared with those supporting factual recall [11]. Consequently, even when older adults struggle with memory details, emotional bonds and feelings of closeness persist. Thus, despite cognitive decline, the capacity for intimacy, empathy, and meaningful connection often endures. The principal emotional and psychosocial challenges faced by octogenarians are further summarized in Table 1.

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Table 1. Key Psychosocial Domains in Octogenarians and Consequences

Domain	Key Issues in Octogenarians	Consequences if Unaddressed
Emotional Intimacy	Limited companionship, affectionate touch, and sexual expression	Loneliness, depressive symptoms, erosion of self-identity
Grief and Loss	Bereavement of spouse/peers, unresolved or complicated grief	Anxiety, prolonged sadness, cognitive and functional decline
Family Dynamics	Role reversals, emotional distance in nuclear families	Loss of autonomy, humiliation, feelings of invisibility
Caregiver Burden	Stress, fatigue, resentment among caregivers	Emotional withdrawal, diminished quality of care
Cultural & Gender Roles	Disproportionate care burden on daughters; isolation of elderly women	Increased risk of neglect, emotional and social distress

Emotional Intimacy and Sexuality in Older Adults

Sexuality and romantic experiences in older adults are often overlooked, even though they play a crucial role in maintaining identity, self-esteem, emotional resilience, and overall mental health. Research shows that many individuals in their eighties and beyond continue to have sexual thoughts, fantasies, and physical intimacy [12]. For men, sexual desire may persist despite physical challenges such as erectile dysfunction or reduced stamina. In women, sexual interest often shifts from physical aspects to emotional closeness, affectionate touch, and verbal expressions of love [13]. Unfortunately, many older adults face barriers to expressing these needs. They may lack partners, live in environments that restrict privacy, or encounter family members and caregivers who hold ageist beliefs that dismiss their desires.

It is important to broaden the understanding of sexuality in late life to include non-sexual forms of intimacy such as memory-based fantasies, emotional connection, handholding, and shared laughter. These forms of intimacy help maintain a sense of self and emotional stability even as physical abilities decline. Additionally, commonly prescribed medications, including antidepressants such as Selective Serotonin Reuptake Inhibitors, antihypertensives such as beta blockers, and many antipsychotics, it can reduce sexual desire and performance [6, 9]. Healthcare providers must therefore carefully balance treatment goals with the preservation of quality of life. Clinicians should routinely assess emotional and sexual health, encourage open discussions, and promote environments that respect older adults' need for intimacy. Training caregivers to respond respectfully, ensuring privacy, and challenging negative stereotypes are essential steps toward more compassionate and comprehensive geriatric care.

Mood Disorders, Grief, and Emotional Challenges

Elderly people face multiple emotional challenges related to declining health, the loss of loved ones, loneliness, cognitive changes, and reflections on life and mortality. Major depressive disorder in later life often presents differently than in younger adults. Rather than persistent sadness alone, symptoms may include somatic complaints such as generalized aches, slowed thinking, or fatigue, which are often misattributed to normal aging rather than recognized as indicators of depression [3, 14]. Anxiety, restlessness, and irritability may also accompany grief or worsen difficulties in coping.

Bereavement is particularly common in octogenarians, and while grief is a natural process, it can sometimes become complicated. Complicated grief is characterized by persistent yearning,

emotional numbness, and functional impairment, and should not be considered a normal or inevitable feature of aging [15]. Social isolation adds to this vulnerability. Evidence indicates that social disconnection significantly increases mortality risk in older adults, comparable to the risks of smoking or obesity [16]. Remembering past loved ones may provide comfort but can also evoke sadness, illustrating the dual nature of memory in the emotional lives of the elderly.

Several therapeutic approaches have demonstrated benefits in managing emotional difficulties in late life. Life-review therapy and group storytelling help older adults find meaning in past experiences [17]. Reminiscence therapy and validation therapy have been shown to reduce symptoms of depression and anxiety, even among individuals with cognitive decline [5, 12]. Creative therapies such as music and art provide valuable outlets for emotional expression and help reinforce a sense of purpose, identity, and vitality in advanced age [18].

New Relationships and Romantic Attachment in Late Life

Even in their eighth decade, many older adults continue to seek emotional closeness, companionship, and meaningful romantic bonds. In residential care settings or community environments, it is not uncommon for septuagenarians and Octogenarians to form new relationships. These connections often bring renewed purpose, enhanced self-worth, and significantly reduced feelings of loneliness [19]. With the demands of earlier life such as employment and parenting behind them, many elders embrace emotional openness, vulnerability, and intimacy with maturity shaped by life experience.

Attachment theory continues to be relevant in this age group. Individuals with secure attachment histories tend to form fulfilling late-life partnerships, while those with insecure or avoidant patterns may face challenges with trust or emotional closeness [20]. Unfortunately, societal and familial reactions to these new relationships can be dismissive or even hostile. Ageist assumptions often frame late-life romance as inappropriate or irrational, leading to unnecessary interference by family members or institutional caregivers. Healthcare professionals must adopt a respectful, supportive approach. By recognizing and supporting relationships with empathy and appropriate boundaries, clinicians can help ensure that the emotional lives of elders are treated with dignity and care.

Family Systems, Emotional Shifts and Role Transitions

Family continues to be one of the most powerful social institutions throughout a person's life. For those in their eighties, the role of family becomes even more central, often forming the core of emotional support, day-to-day care, and a continued sense of identity [15]. Yet, the structure and dynamics of family life have changed dramatically in recent decades, often leading to emotional distance, physical separation, and unfamiliar role reversals within families.

As societies modernize and urbanize, the traditional model of multi-generational households known as Joint Families, prevalent especially in countries like India is rapidly disappearing. With younger family members moving away for work or education, and with the growing emphasis on nuclear family systems, many elderly individuals are left behind, both physically and emotionally [21]. Conversations with children may be limited to necessary updates or financial matters, lacking the warmth and depth that once defined family interactions [14]. As a result, many older adults report feeling invisible or burdensome, a silent grief that goes unspoken but deeply felt. This estrangement is not just social; it has profound psychological consequences.

Emotional isolation in older adults has been linked with depression, anxiety, learned helplessness, and even suicidal thoughts [18, 20]. Unfortunately, age-related emotional struggles are often dismissed or misattributed to normal aging, leading to underdiagnosis and neglect.

Adding to this emotional burden is the experience of role reversal. The transition from caregiver to care recipient can be destabilizing. Adult children, now responsible for managing the finances, health decisions, and housing arrangements of their aging parents, may unintentionally strip them of autonomy. Although these actions are often rooted in concern and love, they can make older adults feel infantilized or powerless [8, 19]. Elders who were once decision-makers and providers may now feel as though their preferences and experiences are no longer valued.

Clinical interviews and case reports describe the psychological toll this reversal takes. Feelings of humiliation and loss of identity are commonly expressed when older adults are excluded from discussions that directly impact their lives, particularly around end-of-life care, mobility, or privacy [16, 20]. To address these issues, healthcare providers and caregivers must adopt a more inclusive and respectful approach. Even elderly patients with mild cognitive decline should be offered the opportunity to participate in decisions regarding their care. Tools like the Aid to Capacity Evaluation (ACE) can help assess decision-making capacity while preserving dignity and autonomy [12, 17]. Respectful communication, shared decision-making, and emotional sensitivity are not just ethical practices, they are essential to supporting the mental health and dignity of our elders in their final chapters of life.

Emotional Labor and Caregiver Burnout in Geriatric Care

While the basic needs of octogenarians are increasingly recognized in geriatric medicine, less attention is paid to the emotional and psychological toll on their caregivers, most often adult children. Providing long-term care, particularly in the absence of institutional support, can be challenging. The cumulative weight of this responsibility, though motivated by love, frequently results in significant emotional fatigue and health deterioration in caregivers. Research consistently shows that caregivers of aging parents experience elevated levels of depression, anxiety, and chronic physical illnesses compared with non-caregivers [11,20]. This burden is compounded when caregiving responsibilities coincide with employment or child-rearing duties. In many families, stress manifests subtly through emotional distancing, irritability, or even resentment, gradually eroding the quality of caregiver-elder interactions.

In such situations, caregiving may become more transactional than relational. Activities like giving medications, coordinating hospital visits, or managing finances can replace meaningful emotional exchanges. Many octogenarians describe this shift with sadness, feeling more like “projects” or “duties” than valued family members [8, 21]. This depersonalization fosters loneliness and declines in emotional well-being and mental health. However, interventions can restore balance. Evidence supports the use of family therapy, respite care services, and caregiver support groups to reduce stress and improve both caregiver functioning and elder quality of life [6]. These therapeutic avenues provide families space to express grief, renegotiate roles, and rediscover emotional reciprocity, promoting well-being for both caregivers and older adults.

The Grandparent & Grandchild Relationship

Interestingly, one of the most emotionally nourishing relationships for octogenarians often comes from their grandchildren. Unlike the more duty-bound or sometimes strained relationship with adult children, grandchildren frequently approach elders with curiosity, admiration, and emotional openness. These interactions, rich in storytelling and shared affection, provide a sense of meaning and continuity to older adults [4, 12]. Psychologically, this relationship supports what Erik Erikson described as the task of "generativity," the desire in older adulthood to contribute to future generations and leave a legacy [22]. Passing down values, wisdom, and family history helps elders feel seen and significant. Studies indicate that intergenerational programs, such as student visits to elder homes or collaborative digital storytelling, enhance both elder self-esteem and youth empathy [11, 22]. These initiatives should be actively integrated into geriatric care as therapeutic tools rather than mere recreational add-ons.

Complex Influences of Culture and Gender in Caregiving

Cultural norms significantly shape caregiving patterns. In many Asian, African, and Mediterranean societies, the expectation that children care for aging parents is deeply rooted [12]. When migration, career demands, or financial constraints prevent this ideal, feelings of guilt, shame, and emotional tension can emerge on both sides, complicating caregiving relationships and often leaving little space for open dialogue. Gender roles further influence eldercare. Daughters are statistically more likely to become primary caregivers, while elderly women are more likely to be widowed and live alone in later life [20]. This gender imbalance highlights the need for gender-sensitive policies, including targeted support for caregiving daughters and outreach programs for socially isolated elderly women.

Clinical and Policy Recommendations

To improve emotional outcomes for both older adults and caregivers, the following strategies are recommended:

1. **Comprehensive Psychosocial Assessments:** Map family relationships, role dynamics, and emotional needs.
2. **Caregiver Education Programs:** Go beyond physical care to include grief counseling, emotional communication, and autonomy support.
3. **Institutional Support Structures:** Provide respite care, intergenerational engagement programs, and community-based elder-care networks.
4. **Legal Protections:** Safeguard older adults' rights in decision-making, financial independence, and protection from emotional neglect.
5. **Cultural Competency Training:** Equip healthcare providers to navigate generational and cultural expectations around aging and care.

Ultimately, caregiving in late life is not merely a duty; it is about preserving dignity, love, and the humanity of those who once gave us everything.

An Under-Recognized Dimension of Geriatric Care & Sexual Boundary Violations

While geriatric care has largely focused on protecting elderly individuals from neglect and abuse, a sensitive yet critical concern remains underexplored: the perpetration of sexual boundary violations by older adults, particularly men aged 70 and above [19]. The prevailing societal belief that aging diminishes sexual interest or capacity often masks a troubling reality that some older men remain sexually active and, in rare but significant cases, become involved in acts of molestation, harassment, or assault.

Contrary to assumptions of complete sexual disengagement in old age, reports and legal data indicate that a small proportion of elderly men have committed sexual offenses. These acts frequently involve victims within their social or domestic environment, such as domestic workers, dependent relatives, or minors under their care [23]. Though detailed age-segregated crime statistics are scarce, the National Crime Records Bureau (NCRB) documents multiple instances of elderly perpetrators charged under POCSO (Protection of Children from Sexual Offences Act) and Section 376 of the Indian Penal Code. In many of these cases, the accused are widowed, emotionally isolated, or suffering from untreated psychological conditions. Motivation may include unresolved grief, unacknowledged sexual frustration, or even early-stage cognitive decline affecting impulse control [16, 20]. These offences are often enabled by power asymmetries within the household, cultural silence around elderly sexuality, and a general reluctance to perceive older men as potential offenders.

HelpAge India, while traditionally focused on elder abuse, has begun acknowledging this complex issue of intergenerational power and misdirected desire. Their 2022 report points out how emotional neglect, loneliness, bereavement, and lack of spousal intimacy can drive inappropriate behavior when not addressed through structured support. In many cultural settings, especially in South Asia, discussions about sexuality in older adults are taboo, leading to silence, shame, and inadequate intervention [9, 24]. Moreover, neurological and psychiatric conditions such as frontotemporal dementia, Parkinson's-related syndromes, and certain prefrontal lobe disorders have been linked to inappropriate sexual conduct due to reduced impulse regulation [14, 23]. Unfortunately, these are often overlooked or misattributed to "normal aging," leaving caregivers and healthcare professionals unprepared to intervene.

Preventing Harm and Promoting Dignity: A Multi-level Response

To address this growing concern, a multi-pronged intervention strategy is an essential one that neither demonizes elderly individuals nor dismisses the emotional and psychological needs underlying their actions, including

1. Sexual Health Counseling should be integrated into routine geriatric care, especially in psychiatry and family medicine clinics. This can offer safe spaces to discuss unmet emotional and physical needs.
2. Elder Care Homes must provide gender-sensitive education and structured interactions to prevent inappropriate behavior, especially in residents with a history of emotional deprivation or mental illness.
3. Routine Psychosocial Screening should assess not only cognitive decline but also behaviors related to sexual disinhibition, boundary violations, and relational ethics.
4. Public Awareness Campaigns, led by institutions like NIMHANS, medical associations, and organizations such as HelpAge India, should work to normalize discussions around elder sexuality, emphasizing respect, safety, and dignity for all.
5. Caregivers and Legal Guardians must be sensitized to monitor at-risk dependents living with elderly men especially in unsupervised or semi-supervised home environments. Training in boundary awareness and emotional support can be crucial.

As India's elderly population is projected to exceed 180 million by 2030 [21], rising urban isolation, living without spouses, and dependence on domestic care create complex emotional landscapes. Addressing sexuality in old age openly and responsibly is vital to prevent covert forms of abuse and ensure a dignified aging process for all.

Clinical, Ethical and Therapeutic Integration

To provide truly comprehensive care for older adults, the healthcare system must broaden its approach beyond mere disease management. A holistic geriatric framework should integrate emotional, relational, and sexual dimensions of aging domains that are often overlooked yet central to quality of life in late adulthood [12, 25]. Clinicians need to be encouraged and trained to engage in sensitive conversations about intimate histories, unresolved grief, spousal loss, and unspoken emotional needs. Recognizing sexuality as a natural and continuing aspect of aging is fundamental to this shift.

Ethically, such care must strike a delicate balance between respecting an elder's autonomy and ensuring their protection. Consent frameworks should be sophisticated enough to address fluctuating cognitive capacity while preserving dignity and avoiding infantilization [5, 26]. Therapeutically, a multimodal approach is essential. Narrative therapy, life-review interventions, creative arts modalities, and tailored cognitive-behavioral therapy (CBT) can support emotional expression, process loneliness, and reduce frustration. Furthermore, psychological screening should be integrated into routine geriatric assessments, identifying early signs of behavioral disturbances and potentially mitigating the overuse of pharmacological treatments. Table 2 summarizes key clinical and policy recommendations for holistic elder care.

Table 2. Clinical and Policy Recommendations for Holistic Elder Care

Intervention Area	**Recommended Strategy**
Psychosocial Assessments	Include emotional needs, grief mapping, family role analysis
Caregiver Support	Training in emotional communication, respite services, support groups
Legal Protection	Safeguards for autonomy, financial independence, and against neglect
Institutional Care	Intergenerational programs, privacy for intimacy, inclusive family education
Clinical Practice	Routine screening for depression, anxiety, and sexual health needs
Cultural Sensitivity	Gender-sensitive eldercare policies and culturally aware interventions

Ultimately, the sensitive issue of sexual boundary violations by elderly individuals underscores the need for a compassionate, evidence-based model of care. By addressing the full spectrum of emotional and sexual realities in older adults without stigma, the healthcare system can foster environments that uphold both safety and dignity, for elders and those around them.

Conclusion

This review underscores that octogenarians often demonstrate remarkable emotional vitality, retaining capacities for intimacy, grief, resilience, and meaning-making even amid age-related physiological decline. Yet, unaddressed psychosocial stressors, bereavement, loneliness, and shifting family roles, heighten risks of depression, anxiety, cognitive decline, and mortality. A paradigm shift in geriatric care is imperative: one that elevates emotional well-being alongside physical health through integrative, age-sensitive, and ethically grounded approaches. Contrary to misconceptions of disengagement, later life often brings profound affective richness and heightened sensitivity, with emotional resilience emerging as a critical determinant of independence and quality of life. Normalizing open discourse on intimacy, grief, and emotional expression, while integrating psychosocial support into clinical practice, is essential. Dignity, connection, and psychological fulfillment are enduring human rights that must guide truly comprehensive, compassionate geriatric care.

Competing Interest

The authors declare no conflicts of interest relevant to this article.

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Ethics Approval

This article is a narrative review based exclusively on previously published literature. It does not involve human participants, animals, patient data, or identifiable personal information. Therefore, ethical approval from an Institutional Ethics Committee was not required.

Author Contributions

All authors contributed substantially to the study, read and approved the final manuscript, and agree to be accountable for all aspects of the work. G.A.: Conceptualization, investigation, literature review, data interpretation, and manuscript drafting. P.V.: Conceptualization, methodology, supervision, manuscript review, and editing.

Data Availability

All relevant data supporting the findings of this study are included within the article.

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A Case Report and Literature Review on Suspected Anti-N-Methyl-D-Aspartate Receptor Encephalitis in a Child with Type 1 Diabetes at Al Sabah Children Hospital, South Sudan

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Abstract *Anti-N-Methyl-D-Aspartate (NMDA) receptor encephalitis is a rare form of limbic encephalitis but represents the most common autoimmune encephalitis in children. Its clinical manifestations and disease course differ from adults in terms of tumor association, neurological presentation, and symptom frequency. While associations with autoimmune diseases such as Graves' disease, autoimmune polyglandular syndrome, and type 1 diabetes have been reported in adults, a link with type 1 diabetes has not previously been described in children. We conducted a case review of a 16-year-old adolescent with known type 1 diabetes admitted to Al Sabah Children's Hospital, Juba, South Sudan. Clinical features, treatment, and outcomes were documented. Literature was reviewed to contextualize findings and highlight diagnostic challenges in resource-limited settings. The patient presented with altered consciousness, seizures, psychotic symptoms, and movement disorder. Following initiation of high-dose corticosteroid therapy, the patient achieved complete recovery within four weeks. This case suggests a possible association between type 1 diabetes and anti-NMDA receptor encephalitis in pediatric patients, an observation not previously documented. Anti-NMDA receptor encephalitis should be considered in pediatric patients with type 1 diabetes presenting with neuropsychiatric symptoms. This case emphasizes the need for improved diagnostic capacity, awareness, and access to advanced neuroimaging and serological markers in South Sudan and other resource-limited settings.*

Keywords *Anti-NMDA Receptor Encephalitis, Autoimmune Encephalitis, Pediatrics, South Sudan, Type 1 Diabetes.*

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Introduction

Anti-N-methyl-D-aspartate receptor autoimmune encephalitis (anti-NMDAR) is the second most common cause of acute demyelinating encephalitis after mixed disturbance encephalitis, surpassing all viral causes [1-5]. Its prevalence in pediatric populations is estimated at 0.6 per 100,000 [6]. Although it can occur across all ages and sexes, it is most frequently observed in children and young adults (15–45 years), with approximately 80% of affected patients being females [2, 7-8]. Anti-NMDAR encephalitis is an antibody-mediated neurological disorder characterized by autoantibodies directed against the GluN1 subunit and the NR2A/NR2B subunits of the NMDA receptor in the hippocampus, leading to the clinical manifestations [9]. The condition may be associated with viral infections, particularly following herpes simplex virus-1 meningoencephalitis, and with certain tumors, most notably ovarian teratomas. However, in pediatric cases, the disease is often idiopathic [10].

Associations with other autoimmune diseases such as Graves' disease, type 1 diabetes, and autoimmune polyglandular syndrome have been reported in adults, reflecting the shared genetic, pathophysiological, and environmental characteristics of autoimmune disorders [11].

Clinically, patients typically present with acute behavioral changes (irritability, tantrums, manic symptoms, behavioral outbursts, sleep dysfunction, hyperactivity, or coma), seizures (focal, motor, complex partial), dystonia, status epilepticus, memory deficits, catatonia, dyskinesia (including orofacial dyskinesia), speech disturbances (mutism or reduced responsiveness), autonomic dysfunction, and hypoventilation [7]. Diagnosis is confirmed by a **10-fold increase in cerebrospinal fluid levels of anti-NMDA receptor antibodies**, which remains the gold standard. Neuroimaging is often normal, with MRI abnormalities present in only 50% of cases, typically showing nonspecific hippocampal hyperintensities on T2/FLAIR. Electroencephalography (EEG) frequently reveals abnormal slow or disorganized activity, and in rare cases, the characteristic "extreme delta brush" pattern [7].

Immunotherapy is the mainstay of treatment, with tumor removal indicated when an underlying neoplasm is identified [12-14]. The disease can be severe in the acute phase, with a mortality rate of about 5%. Relapses occur in approximately 15% of patients. Despite these challenges, functional outcomes are generally favorable, although neuropsychological and psychiatric sequelae remain relatively common [14]. Early administration of immunotherapy improves outcomes and reduces relapse risk [14].

Case Presentation

History

A 16-year-old male adolescent with a known history of type 1 diabetes mellitus since the age of five, managed with insulin (Mixtard) at 1 IU/kg/day (28 IU in the morning and 14 IU in the evening), presented with acute neurological symptoms. His diabetes was reported to be well controlled.

Two weeks prior, he had been admitted to the Intensive Care Unit at Juba Teaching Hospital with cerebral malaria and diabetic ketoacidosis (DKA), treated successfully, and discharged after seven days. Unfortunately, 5 days after discharged from Juba Teaching Hospital, he was admitted to Mauna Medical Centre for 24 hours treatment for recurrent DKA and cerebral malaria, with no improvement. Ultimately he was referred to Al Sabah Children Hospital.

At presentation, he had a one-day history of high-grade persistent fever unresponsive to paracetamol or tepid sponging. The fever was associated with abnormal body movements characterized by recurrent episodes of flexion

and extension of both upper and lower limbs, each lasting less than one minute. These episodes were accompanied by upward rolling of the eyeballs and drooling of saliva, but without sphincter incontinence. He also reported upper respiratory symptoms (cough and sneezing) five days prior to the onset of neurological manifestations.

Examination

On arrival, the patient appeared acutely ill and comatose, with a Glasgow Coma Scale score of 6/15. He was febrile (temperature 38.8°C), with mid-sized pupils bilaterally reactive to light. The remainder of the physical examination was unremarkable.

Investigations

The followings were the investigations requested with their results:

1.Random blood glucose: 433 mg/dl 2. Urinalysis: WBCs 10–15 cells/HPF, numerous pus cells, positive leukocyte esterase, glucose +++, ketones +++ 3. Widal test: reactive for *Salmonella enterica* 4. Complete blood count: WBC 3.5 × 10⁹/L, lymphocytes 40%, granulocytes 78%, hemoglobin 10 g/dl, platelets 420,000/µL 5. Serum electrolytes, urea, and creatinine: within normal limits.

Initial Impression

The working diagnosis was coma secondary to severe diabetic ketoacidosis, cerebral malaria, enteric fever, and urinary tract infection.

Differential Diagnosis

Bacterial meningitis and meningoencephalitis.

Management and Outcome

Treatment

The patient was started on:

- Artesunate 2.4 mg/kg at 0, 12, and 24 hours, then once daily for 2 days
- Dexamethasone 0.6 mg/kg/day in 4 divided doses
- Cefepime 50 mg/kg every 12 hours
- Vancomycin 20 mg/kg in 30 ml of normal saline every 8 hours
- Maintenance fluids (normal saline) for DKA
- Acyclovir 20 mg/kg every 8 hours via nasogastric tube
- Anticonvulsants:
  - Phenytoin: loading dose 20 mg/kg, reloaded twice with 10 mg/kg each (maximum 40 mg/kg), then 5 mg/kg in 2 divided doses
  - Phenobarbitone: loading dose 20 mg/kg, reloaded twice with 10 mg/kg each (maximum 40 mg/kg), then 5 mg/kg in 2 divided doses
- Regular insulin at 0.1 IU/kg/hour

Clinical Course

Thirty-six hours after admission, the patient improved from DKA with stabilization of metabolic status. His Glasgow Coma Scale rose to 13/15 (awake but confused). However, he developed left-sided weakness affecting both upper and lower limbs, with complete loss of movement and sensation. Neurological examination revealed loss of the left nasolabial fold, deviation of the mouth to the right, and inability to swallow solids and liquids.

A brain CT scan was requested with an impression of stroke secondary to CNS infection. The scan, performed after 7 days (without contrast), was unremarkable.

On the fifth day of admission, the patient became unresponsive to voice and pain. He developed repeated episodes of movement disorder characterized by lip smacking, limb flailing, eye blinking, and hyperextension of the neck and trunk, each lasting 30–60 minutes.

By the tenth day, he regained responsiveness with partial improvement in limb movement, swallowing, and restoration of the nasolabial fold. However, he developed psychotic symptoms, including hallucinations and delusions. He repeatedly reported hearing the voice of his elder sister (who had died eight

months earlier) calling him to follow her, expressed fear of imminent death, and exhibited excessive talking for several hours without sleep for more than 16 hours.

Impression

Based on the clinical course, the impression was autoimmune encephalitis, most likely anti-NMDA receptor encephalitis. However, due to lack of access to cerebrospinal fluid antibody testing (gold standard), MRI, and electroencephalography in our setting, the diagnosis could not be confirmed.

Definitive Management

The patient was initiated on prednisolone 2 mg/kg/day and haloperidol 5 mg orally once daily.

Within 5 days of treatment, he showed a remarkable improvement with reduction in movement disorders, seizures, and behavioral symptoms. After 25 days of admission, his symptoms had completely resolved.

Outcome

The patient was discharged home with significant improvement and linked to the outpatient follow-up clinic for continued care.

Discussion

Anti-N-methyl-D-aspartate receptor autoimmune encephalitis (anti-NMDAR) is the second most common cause of acute demyelinating encephalitis after mixed disturbance encephalitis, surpassing all viral causes. It is characterized by the subacute onset of short-term memory loss, behavioral changes, and seizures involving the medial temporal lobe and amygdalae [1-5, 15, 16].

The condition was first described by Dalmau et al. in 2007 [7]. It occurs across all ages and sexes but is most frequently seen in children and young adults (15–45 years), with approximately 80% of cases reported in females [7, 8]. Our patient, a 16-year-old male adolescent, falls within the commonly affected age group described in the literature.

Anti-NMDAR encephalitis may be associated with viral infections, particularly following herpes simplex virus-1 meningoencephalitis, and with certain tumors, most notably ovarian teratomas. In pediatric cases, however, the disease is often idiopathic [9]. Our patient had preceding upper respiratory symptoms (cough, rhinorrhea, and sneezing), which may suggest a viral trigger. Given that tumor-associated cases are more common in females and older patients, malignancy was considered less likely in this case.

Associations with other autoimmune diseases such as Graves' disease, type 1 diabetes, and autoimmune polyglandular syndrome have been reported in adults, reflecting shared genetic, pathophysiological, and environmental factors [10]. However, no study has documented anti-NMDAR encephalitis in pediatric patients with type 1 diabetes. This case therefore represents the first reported suspected association between type 1 diabetes and anti-NMDAR encephalitis in a child.

The clinical presentation of anti-NMDAR encephalitis differs between adults and children. In adults, psychiatric symptoms (67%), cognitive impairment (19%), and seizures (14%) are the most common initial manifestations, particularly in females. In contrast, children typically present with non-psychiatric symptoms such as seizures (72%), with focal seizures (42%) being the most frequent, followed by status epilepticus and later behavioral disturbances [17]. Our patient initially presented with seizures that progressed to status epilepticus, followed by behavioral changes, consistent with pediatric patterns described in the literature.

The hallmark of anti-NMDAR encephalitis is a 10-fold increase in cerebrospinal fluid antibody titers, which remains the gold standard for diagnosis. Unfortunately, this test was unavailable in our setting. Brain CT findings are typically normal, as was the case for our patient. MRI abnormalities are seen in 40–50%

of patients, usually nonspecific hippocampal hyperintensities on T2/FLAIR sequences, but MRI could not be performed due to financial constraints. Electroencephalography often shows generalized slow or disorganized activity, and in rare cases, the characteristic "extreme delta brush" pattern. However, EEG was also unavailable in our pediatric facility.

Immunotherapy remains the cornerstone of treatment, with corticosteroids, intravenous immunoglobulin, and plasma exchange as first-line options. Rituximab and cyclophosphamide are reserved for refractory cases [12-14]. Our patient was treated with high-dose corticosteroids (prednisolone), to which he responded favorably. Therapy was tapered over four weeks following recovery and subsequently discontinued.

Anti-NMDAR encephalitis can be severe in the acute phase, with a mortality rate of approximately 5%. Relapses occur in about 15% of patients. Despite these risks, long-term outcomes are generally favorable, although neuropsychological and psychiatric sequelae are relatively common [12-14]. Early initiation of immunotherapy improves prognosis and reduces relapse risk. Our patient responded well to corticosteroid therapy within a short duration, further supporting the clinical impression of autoimmune encephalitis.

Conclusion

This case demonstrates the importance of considering anti-NMDA receptor encephalitis in pediatric patients with type 1 diabetes or other autoimmune diseases who present with refractory status epilepticus, psychiatric symptoms, and movement disorders. Despite the absence of confirmatory tests, advanced imaging, and EEG, the patient responded well to corticosteroid therapy, highlighting the importance of clinical vigilance. The case underscores the urgent need to strengthen intensive care services, diagnostic infrastructure, human resource capacity, and health financing mechanisms to improve outcomes for complex pediatric neurological conditions in South Sudan.

At the same time, the case highlights the systemic challenges faced in South Sudan: limited intensive care capacity, lack of access to cerebrospinal fluid antibody testing, MRI, and EEG, shortages of trained pediatric neurologists, and absence of health insurance mechanisms to cover advanced diagnostics and prolonged ICU care. These gaps underscore the urgent need for policy and infrastructure development to improve outcomes for children with complex neurological conditions.

Recommendations

The followings are the agreed recommendations by the authors:

1. **Intensive Care Unit strengthening:** Establish an ICU unit and equip with necessary equipment like ventilatory support, monitoring equipment, and trained pediatric critical care staff.
2. **Diagnostic facilities:** Establish access to CSF antibody testing, MRI, and EEG to enable timely and accurate diagnosis of autoimmune encephalitis.
3. **Human resources:** Invest in training pediatric neurologists, and ICU nurses in recognition and management of autoimmune neurological disorders.
4. **Health insurance:** Introduce affordable insurance schemes to reduce out-of-pocket costs for families requiring advanced diagnostics and prolonged ICU care.
5. **Policy development:** Formulate national policies to integrate rare autoimmune diseases into child health programs, ensuring funding for diagnostics, treatment, and follow-up.

Limitations

1. **ICU constraints:** Limited critical care beds and equipment restricted monitoring and supportive management.

2. **Diagnostic gaps:** Absence of CSF antibody testing, MRI, and EEG prevented definitive diagnosis.
3. **Human resource shortages:** Few trained pediatric neurologists and ICU specialists hindered comprehensive care.
4. **Financial barriers:** Lack of health insurance forced reliance on out-of-pocket payments, limiting access to advanced investigations.
5. **Policy gaps:** No national framework exists for rare pediatric autoimmune diseases, leaving hospitals without structured support.

Lessons Learned

1. **Clinical suspicion is vital:** In the absence of confirmatory tests, careful clinical observation and response to immunotherapy can guide diagnosis.
2. **ICU readiness matters:** Strengthening pediatric ICU services is essential for managing prolonged seizures, movement disorders, and altered consciousness.
3. **Diagnostics drive outcomes:** Access to antibody testing, MRI, and EEG would have allowed earlier confirmation and tailored management.
4. **Human resources are critical:** Training and retaining pediatric specialists is key to improving recognition and treatment of rare neurological conditions.
5. **Insurance and policy support:** Affordable health insurance and national policies are needed to reduce financial barriers and ensure equitable access to care.

Declaration

Written informed consent for publication was obtained from the patient's parents.

Competing interests

None.

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Ethical Approval

Not applicable. This is a case report.

Author's contributions

JP drafted the case report, literature review, and conclusion with recommendations, while JL and KS reviewed, expanded it, and edited. All reviewed the final manuscript and agreed on the final version.

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Data Availability

The data generated and analyzed from this case report is available on reasonable request from the authors of this case report.

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Integration of Traditional Medicine into the Management of Malnutrition in Mali: A Pilot Study in Bamako District

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Abstract *Childhood malnutrition remains a major public health challenge in Mali, where acute malnutrition affects nearly 9% of children under five, conventional treatment coverage remains low, and 70–80% of the population first seeks traditional medicine. This pilot study aimed to describe practices, perceptions, and interactions among traditional pediatric practitioners (TPPs), mothers, healthcare workers, and community leaders regarding childhood malnutrition in Bamako, and to identify factors enabling or hindering collaboration between traditional and conventional health systems. A descriptive qualitative study was conducted from February to April 2021 in three Bamako communes (II, IV, and V), combining semi-structured interviews and focus group discussions with 4 TPPs, staff from 3 community health centers (CHCs), and 13 community leaders, alongside anthropometric screening (mid-upper arm circumference, weight-for-height, and height-for-age) of 302 children aged 6–59 months attending traditional consultations. TPPs reported substantial daily attendance for common pediatric conditions, while malnutrition was rarely recognized by families or practitioners. Screening nevertheless identified 15.8% global acute malnutrition and 14.2% stunting. TPPs, mothers, and healthcare workers were generally receptive to strengthened collaboration, including MUAC training and bidirectional referral. Key barriers included the absence of formal referral pathways, divergent understandings of malnutrition, and limited feedback to TPPs. Involving TPPs in nutritional screening and awareness-raising appears feasible and could facilitate earlier detection among children who may otherwise remain outside the formal health system. Operational research with quantitative impact evaluation is warranted to confirm these findings.*

Keywords *Child Malnutrition, Intersectoral Collaboration, Mali, Primary Health Care, Traditional Medicine, Traditional Practitioners.*

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Introduction

Childhood malnutrition remains a major public health problem in Mali and more broadly across sub-Saharan Africa. In 2018, the prevalence of global acute malnutrition (GAM) among children under five years of age was still approximately 9% in Mali, including around 2% with severe acute malnutrition (SAM), while approximately 27% suffered from chronic growth faltering or stunting [1]. Despite a slight improvement compared with previous years, these rates remain concerning and are close to the WHO emergency threshold in some regions. In addition, infant and young child feeding practices remain inadequate: fewer than 10% of children aged 6–23 months receive a minimum acceptable diet according to national surveys [1]. This situation contributes to high child mortality, with malnutrition being associated with nearly half of all deaths among children under five years of age [2].

In response to this burden, Mali has integrated the management of acute malnutrition into its health system for more than a decade. A National Protocol for the Integrated Management of Acute Malnutrition (IMAM) has been in place since 2011 and was revised in 2017. It includes simplified approaches aimed at decentralizing treatment to the community level. These approaches involve community health workers (CHWs), who use mid-upper arm circumference (MUAC) as the sole diagnostic criterion and a single ready-to-use therapeutic food (RUTF) product to treat both moderate and severe acute malnutrition. A pilot study conducted in 2020 in Commune I of Bamako (the OptiMA Bamako project implemented by the NGO ALIMA) suggested that this MUAC-only strategy using a single product was effective, achieving a recovery rate of approximately 90% and mortality below 1% among treated malnourished children [3]. However, the study highlighted low program coverage: among an estimated 3,000–5,000 children with acute malnutrition in the area, only 615 actually received treatment [4]. This finding reflects a broader problem: in many high-prevalence settings, fewer than one in five children with severe acute malnutrition has access to available nutritional treatment services [4]. Multiple barriers to access - including distance to health facilities, transportation costs, limited RUTF stocks, mothers' workload, inadequate knowledge, and cultural perceptions - reduce the effectiveness of conventional malnutrition control programs [5].

At the same time, traditional medicine plays a prominent role in health-seeking behavior in Mali. According to the World Health Organization, approximately 80% of the African population initially seeks care from traditional healers for common health conditions [6-8]. In Mali, an estimated 70–80% of the population consults traditional medicine practitioners and uses traditional pharmacopoeia before turning to the conventional health system [8, 9]. This preference can be explained by several factors, including proximity to and trust in traditional practitioners, who have long been embedded within communities; the relatively low cost of traditional treatments; and strong cultural and religious considerations [2]. Traditional healers, including traditional pediatric practitioners (TPP) and herbalists, are often perceived as more accessible and attentive, with knowledge rooted in local traditions and beliefs, whereas modern medicine may sometimes be perceived as distant or foreign [6]. There is also a very dense network of traditional practitioners: in some areas of Ghana, there is reportedly one traditional healer for every 200 inhabitants, compared with one physician for every 25,000 inhabitants, illustrating their de facto role as first-contact providers [7].

Recognizing this reality, the Malian government is among the few governments in Africa to have officially recognized traditional medicine and sought to integrate it into the formal health system [6]. A Department of

Traditional Medicine was established within the National Institute of Public Health, and several plant-based remedies have been tested and officially approved, with seven already included on the national essential medicines list [6]. Nevertheless, this integration has so far focused primarily on product regulation, particularly improved herbal medicines, and collaboration for specific diseases. There are currently no national guidelines involving traditional practitioners in the detection or management of acute malnutrition. Given the magnitude of the nutritional problem and the high utilization of traditional healers by the population, it is relevant to assess the extent to which these community-based actors could contribute to nutritional surveillance, prevention, and even treatment of malnutrition, as a complement to the conventional health system.

In this contextual background, we conducted a pilot study in the Bamako health district to explore the integration of traditional medicine practitioners, practices, and products into nutrition activities within health services. The objective of this phase was to understand current practices, perceptions, and interactions between traditional and conventional medicine regarding childhood malnutrition, in order to identify enabling factors and barriers to potentially strengthened collaboration.

Materials and Methods

Study Design

This was a descriptive qualitative study conducted as part of a two-phase action-research process. The first phase (2020–2021) consisted of interviews and observations aimed at establishing a baseline assessment of practices and attitudes. The methodology combined individual semi-structured interviews, focus group discussions.

Study Setting

The study was conducted in the Bamako District, the capital of Mali, specifically in three urban communes (Communes II, IV, and V) where highly frequented traditional pediatric care sites are located. The Bamako health district is an administrative and health-management entity under the Ministry of Health and Public Hygiene through the National Health Directorate. Located on the left bank of the Niger River, the city comprises six communes (I to VI), each equipped with community health centers (CHC) and a referral health center (RHC) providing specialized care [10]. According to the 2009 General Population and Housing Census (RGPH), Bamako had approximately 1.81 million inhabitants, with a population density exceeding 3,500 inhabitants/km². By 2025, the population was estimated at 2.5–3 million due to a high annual population growth rate [11, 12]. (9,10). The population is young, with approximately 45% under 15 years of age, while around 25–27% are women of reproductive age, directly influencing demand for maternal and pediatric health services.

The health system is hierarchically structured. community health center (CHC) provide first-line healthcare and preventive services, while referral health center (RHC) provide specialized care and manage severe acute malnutrition. Referral hospitals such as Gabriel Touré Hospital and Point G Hospital provide tertiary care, including surgery and specialized pediatric services, although physician density remains relatively low (approximately one physician per 10,000 inhabitants) [10].

Bamako town faces major health challenges, including malaria, respiratory infections, diarrhea, and malnutrition, with an estimated prevalence of global acute malnutrition of approximately 9% among children under five years of age [13]. Rapid urbanization and inequalities in access to healthcare, particularly in peripheral communes, together with the persistence of traditional medicine and inadequate coverage of nutrition programs,

constitute major obstacles to local public health [14].

Study Population and Sampling

The study population consisted of traditional pediatric practitioners (TPP), mothers of children under five years of age, healthcare workers, and community leaders. In collaboration with the Malian Federation of Traditional Therapists and Herbalists (MFTTH), we selected four well-known and active traditional pediatric practitioners (TPP) - two women and two men, with a mean age of 52 years - who agreed to participate. Their treatment sites were located in the Médina-Coura and Bakaribougou markets (Commune II), Djikoroni Para (Commune IV), and Sabalibougou (Commune V).

In parallel, three corresponding community health centers (CHC) were included to interview conventional healthcare providers, one per commune. Finally, the local community was involved through 302 mothers of children under five years of age who attended consultations with the TPP during the study, as well as 13 community leaders, including members of community health associations, religious leaders, and teachers, identified with the assistance of community outreach workers.

Eligibility and Selection Criteria

Selection was Based on the Following Criteria:

The sample size was not determined a priori on the basis of a predefined theoretical data saturation threshold. Instead, the study adopted an exhaustive purposive sampling strategy, including all mothers and children attending the four selected traditional medicine practitioner (TMP) sites throughout the three-month data collection period, as well as all traditional medicine practitioners, healthcare providers, and community leaders who were accessible within the study municipalities. Thus, sampling was exhaustive within the predefined study sites rather than guided by data saturation. This approach is consistent with previous research investigating the capacity of Malian traditional medicine practitioners and herbalists to integrate nutrition-related activities [15]. However, it limits the potential for statistical extrapolation of the reported proportions.

For TPPs, sites providing traditional pediatric care and receiving the highest patient attendance were considered, with one TPP selected per site. When more than one traditional pediatric practitioner was operating at a given site, the practitioner receiving the largest number of children per day was selected. A total of four TPPs sites were selected in three communes of the Bamako District: two sites in Commune II, one in Commune IV, and one in Commune V. Health areas were selected based on the presence of TPP treatment sites providing care to children with various diseases.

A total of three corresponding community health centers were selected in the three communes hosting the selected TPPs. All mothers of children under five years of age who attended consultations during the study period were included. Community leaders were identified in collaboration with community outreach workers.

Data Collection Process

Two teams led by experienced supervisors conducted the interviews between February and April 2021.

Interviews with the four TPPs were conducted at their workplaces in Bambara, using an interview guide exploring, among other issues, the types of childhood illnesses they routinely managed; their response to a suspected case of malnutrition, including visible wasting and edema; possible referrals to hospitals; existing collaboration, or lack thereof, with health facilities; and their perceptions of why families preferentially seek traditional medicine.

Mothers and accompanying caregivers (302 participants, some participating in focus groups

of 5–8 people) were interviewed immediately after their child's consultation with the TPP. The interviews documented their therapeutic pathways: which symptoms or beliefs prompted them to take their child to a traditional healer or, alternatively, to a CHC; which home remedies had been administered before consultation; and which infant feeding and nutritional prevention practices were followed at home.

Interviews with healthcare personnel - physicians or nurses responsible for nutrition activities at the CHC - focused on their experience with patients arriving after consultation with a traditional healer, the existence of communication or referral mechanisms with traditional practitioners, and their suggestions for improved collaboration.

Finally, 13 community leaders were consulted regarding collective attitudes toward both forms of medicine, beliefs surrounding malnutrition, and possible community-based actions for its prevention.

Data Processing and Analysis

Interviews were transcribed and subsequently subjected to manual thematic analysis. Responses were coded to identify major patterns and significant quotations (verbatim) illustrating participants' views.

Given the qualitative nature of the study and the empirical sampling approach, no statistical generalization was attempted. Any numerical proportions derived from the sample - for example, the percentage of mothers mentioning a particular reason - are presented for illustrative purposes only and should not be extrapolated to the wider population.

Ethical Considerations

To ensure respect for human rights throughout the study, an authorization request was submitted to the ethics committee of the Malian Federation of Traditional Therapists and Herbalists (MFTTH), which issued a favorable opinion. To facilitate integration within the health areas, a separate data-collection authorization request was submitted to the local health authorities and approved.

During the interviews, particular attention was paid to obtaining informed consent from participants and protecting the confidentiality of the information collected. The anonymity of each participant was strictly maintained. All information collected was used exclusively for the purposes of this research.

Results

Profile of Traditional Pediatric Practitioners and Working Conditions

The four traditional pediatric practitioners (TPPs) interviewed, including two women, were aged between 45 and 65 years, with a mean age of 52 years, and had been practicing traditional pediatrics for an average of 21 years.

They received a substantial flow of pediatric patients. According to their estimates, they saw approximately 30 children under five years of age per day on average, although attendance varied considerably by site, ranging from five children per day in Bakaribougou to approximately 100 per day in Djikoroni Para, a highly frequented market.

The traditional healers conducted consultations themselves, established traditional diagnoses, and administered plant-based remedies, including infusions, decoctions, powders, and ointments, which they either prepared or sold on site.

When asked about the origin of their knowledge, all participants emphasized intergenerational family transmission.

One participant stated:

> *"I inherited my knowledge of traditional pediatrics from my grandfather and then my father, and I am now training my daughter so that she can preserve the tradition."*

Another well-known herbalist explained:

> *"My mother taught me everything. Today, together with my sisters, we train our own children as well as our family assistants in this knowledge."*

This family-based transmission ensures continuity of traditional practices but also indicates that each TPP operates within a relatively closed family network, potentially limiting knowledge sharing outside this circle. This may represent a challenge for integration with the formal health system.

Diseases Managed in Traditional Pediatric Care

The most frequent reasons for consultation reported by the TPPs were remarkably similar to those encountered in CHC among children.

Malaria and disorders associated with teething, including infant gingival syndromes, were the most frequently cited conditions, mentioned by all four traditional practitioners.

These were followed by oral candidiasis (thrush), abdominal pain and suspected parasitic infections, tonsillitis and cough associated with acute respiratory infections, common cold, and otitis.

This pattern indicates that, from the perspective of traditional healers, they primarily manage common childhood illnesses.

Notably, malnutrition itself was not spontaneously mentioned among the most common conditions. In other words, traditional practitioners did not appear to consider visible wasting or nutritional edema as a primary reason for consultation. Such manifestations are likely interpreted differently, for example as "loss of appetite" or as a symptom of an underlying disease, rather than being recognized as a distinct clinical condition by healers or parents.

However, when asked about their management of visibly malnourished children who were severely wasted and/or had bilateral foot edema, their responses varied.

Two TPPs reported systematically referring such children to hospitals or CHC because they did not have appropriate therapeutic foods:

> *"I refer every child I see who is too thin to the health center because I do not have Plumpy'Nut or other products to treat them."*

These practitioners appeared to have incorporated messages received through previous nutrition-awareness activities. They reported having previously participated in training organized by the Ministry of Health on malaria and diarrhea management, during which malnutrition had also been discussed.

By contrast, the other two traditional healers acknowledged that they personally managed some cases of moderate malnutrition:

> *"I receive few malnourished children, but when they come, I treat them with plants that stimulate appetite and strengthen the child."*

According to these practitioners, such plants "give strength" or act as rehydrating agents, although no further details were provided.

None of the practitioners had an enriched therapeutic formula or specific nutritional supplement. Instead, they used empirical remedies such as broths made from nutrient-rich leaves, revitalizing roots, and other traditional preparations whose efficacy has not been documented.

Referral to Health Facilities and Existing Collaboration

All traditional practitioners interviewed stated that they had previously referred patients to hospitals or CHC, at least for certain severe conditions.

Severe malaria was the most frequently cited reason for referral, followed by acute diarrhea with dehydration and persistent vomiting.

One healer also reported referring patients with severe anemia, particularly infants with marked pallor, as well as infants with dehydration.

However, the interviews revealed that there was no formal referral or counter-referral system between the two medical systems.

Referrals were informal and one-directional:

> *"I write a short note that the mother gives to the doctor, or I tell her to go quickly, but I am not informed about the follow-up."*

None of the TPPs received feedback regarding the outcomes of patients they had

referred to hospitals, and no official referral forms were used.

Similarly, healthcare providers at health centers confirmed that they had no formal protocol for referring patients to traditional practitioners—which would in any case be inconsistent with official practice—even though they acknowledged that, informally, they might recommend herbal teas or traditional massage as supportive measures.

Despite the absence of a formal framework, a minority of healthcare workers and traditional practitioners had established personal contacts.

For example, a head nurse at a CHC reported:

"I helped two traditional therapists from my neighborhood obtain their MFTTH membership cards. Since then, we have known each other well, and they do not hesitate to refer complicated cases to me."

Such individual initiatives remain rare and depend largely on interpersonal relationships. Most healthcare workers interviewed acknowledged that they did not personally know the traditional practitioners working in their health areas, and vice versa.

Mothers' Perceptions and Therapeutic Pathways

Among the 302 mothers or caregivers interviewed at traditional medicine sites, a very large majority reported regularly consulting TPPs for their children's healthcare.

More than 40% stated that they had consulted the same healer "for as long as they could remember" and could not quantify the number of visits. Some reported coming to the market every week and taking the opportunity to seek advice or obtain remedies.

Approximately 24% were visiting the practitioner for the first time, often because of the practitioner's reputation or a recommendation from a female relative. The remainder had consulted the practitioner two or three times within the previous six months.

This demonstrates strong client loyalty toward traditional practitioners perceived as effective, effectively providing an alternative form of continuity of pediatric care.

When asked why they preferred traditional medicine for their children, mothers primarily cited perceived quality of care and treatment outcomes.

The most frequently recurring theme was the warm reception and attention given to the child:

"At the TPP site, we are welcomed well; they take time to listen to the mother and reassure her. At the health center, they rush through the consultation."

The perceived effectiveness of traditional remedies, particularly for certain conditions, was another major reason:

"Modern medicines do not completely cure my child's illnesses, whereas with the TPP's plants, the child gets better faster and the illness does not come back."

Several mothers cited recurrent oral candidiasis or difficult teething episodes:

"The plants used to paint the mouth are much more effective than the syrups they sell in pharmacies."

Another stated:

"A child washed with plants against 'badigenou' [convulsions/teething] becomes stronger, whereas children treated at the hospital remain fragile."

Affordability was another frequently cited reason. Traditional consultations cost between 500 and 1,000 CFA francs - less than €2 - and remedies were often prepared on site from inexpensive local ingredients, whereas:

"At the pharmacy, the syrup costs 5,000 CFA francs."

Finally, many mothers expressed strong cultural beliefs:

"Traditional medicines treat the root of the problem; they drive away what causes the illness - the evil spirits, the evil eye."

Thus, beliefs and protective practices played an important role. Some childhood illnesses were perceived as resulting from witchcraft or

the “djatigi” (evil eye), requiring rituals and protective herbs that only traditional medicine could provide.

Some mothers reported bringing their children periodically to the TPP even when they were healthy, in order to “strengthen them and protect them from disease.”

It is important to note that very few mothers spontaneously mentioned distrust of modern medicine. Their preference for TPPs appeared to be based primarily on positive perceptions of effectiveness and cultural trust rather than active rejection of health centers.

Nevertheless, when asked what discouraged them from attending CHC, several mothers described the “accessing healthcare was an uphill battle” associated with public health facilities, including waiting times, paperwork, prescriptions that had to be purchased, injections, and occasionally brusque attitudes from healthcare personnel.

One mother summarized this as follows:

“At the hospital, they make you pay to tell you that the child is not seriously ill, or they give you two medicines. Here at the market, the traditional medicine practitioner takes the child on her lap and immediately gives you something to relieve him.”

Household Prevention Practices and Use of Home Remedies

The interviews provided greater insight into how these families attempt to prevent malnutrition and illness in their daily lives before seeking professional healthcare.

Regarding the feeding of young children, mothers reported a variety of foods given to children aged 6–23 months, but overall, few were nutrient-dense.

Breastfeeding was widely practiced and was mentioned by 18% of respondents as a basic food source, which is a positive practice. However, complementary feeding was often based on a limited variety of foods.

Rice was the most frequently mentioned food (17% of responses), followed by cereal porridges made from millet or sorghum and the *dégués* sweetened porridges, as well as low-nutrient foods such as industrial chips and snacks (9%), bread soaked in tea (7%), and others.

Protein- and micronutrient-rich foods such as meat, fish, eggs, fruits, and vegetables were rarely mentioned spontaneously or were mentioned by only a small proportion of respondents. A few mothers mentioned fish soup or potatoes, while almost none mentioned green vegetables or eggs.

This confirms low dietary diversity among young children in our sample, probably related both to culinary practices - where children are often fed the same basic foods as adults, such as rice with sauce - and to economic constraints.

Some mothers acknowledged this deficiency and reported trying to “give foods rich in vitamins” whenever possible, such as fish or small amounts of meat added to the child's porridge.

For the prevention of malnutrition, mothers' responses mainly focused on well-known good feeding practices:

“Feed the child regularly and monitor what he eats.”

“Do not wait; give him enriched porridge and soup in addition to the family meal.”

“Exclusive breastfeeding until six months, followed by gradual introduction of porridges and soups.”

These responses clearly reflect the impact of health-center and community-based education campaigns promoting exclusive breastfeeding and dietary diversification.

However, few mothers mentioned more specific practices such as adding oil or peanut butter to porridge to increase its energy density, or growing vegetables. This may indicate insufficient knowledge of nutrient-dense recipes or limited access to the necessary ingredients.

Regarding general disease prevention, mothers combined modern and traditional approaches.

More than half reported systematic use of insecticide-treated bed nets for children at night to prevent malaria, indicating that this public health message has been widely adopted.

However, traditional remedies also played a major role. Many mothers reported regularly giving their children herbal decoctions as preventive preparations, such as "strengthening" herbal teas after birth or weekly anti-malaria decoctions based on neem or mugwort.

Nearly 20% of mothers stated that they "regularly consulted the TPP even when the child was well, for a check-up and advice."

Some mothers also reported using amulets "gris-gris" to protect their children against any misfortune.

By contrast, only a few mentioned hygiene-related measures such as:

"Avoid giving yesterday's leftovers to the child."

"Give the child clean water."

"Keep the child warm and protected from drafts."

Such responses were less common than traditional preventive practices.

When a child became ill, most mothers initially used home-based treatments before seeking external medical care.

More than half - approximately 53% - reported administering traditional home remedies as soon as symptoms appeared.

For example, in cases of fever or suspected malaria, mothers administered decoctions made from local bitter leaves. For diarrhea, they used herbal teas prepared from roots or baobab juice, which was believed to have antidiarrheal properties.

For teething problems, they used herbal mouth rinses or applied traditional ointments to the gums. For oral thrush, some used gauze swabs soaked in guava-leaf decoctions.

These family recipes are transmitted across urban communities in Bamako.

Approximately 14% of mothers also used modern medicines through self-medication, generally over-the-counter bought syrups such as cough syrup, paracetamol syrup, or teething preparations.

Nearly one in five mothers administered no treatment before consultation, often because the illness was considered immediately severe or unusual, or because they did not know what to do.

Symptoms prompting consultation with traditional practitioners largely overlapped with those reported by the TPPs.

Many mothers sought care for recurrent oral candidiasis, presumed malaria-related fever, persistent diarrhea, vomiting, loss of appetite or weight loss, skin rashes, or unexplained crying that some attributed to an "evil spell or curse" requiring a herbal bath.

Loss of appetite was particularly common: "He no longer eats anything. I am afraid he will waste away, so I take him to the TPP to restore his appetite."

Behind this notion of "loss of appetite" may lie cases of moderate or severe malnutrition that mothers do not recognize as such, instead interpreting the symptom as evidence of illness or a supernatural influence.

This confirms the importance of raising awareness about the signs of malnutrition. Many mothers never use the term "malnutrition" (kujanginé in Bambara) and may not understand the medical concept, even though they notice that their child is becoming thinner.

Finally, a non-negligible proportion of mothers - approximately 5% - reported combining the two medical systems according to their needs.

For example: "I first go to the CHC for vaccinations, fever, and so on, but if the child does not improve, or for certain illnesses such as 'da [signature]', I prefer the TPP."

Another mother stated: "The two systems complement each other. I have no hesitation in going to the hospital for serious problems, but I always return to the traditional therapist to consolidate the recovery."

These accounts and testimonies demonstrate that, in practice, some families already adopt a pragmatic complementary approach. They are not necessarily opposed to biomedicine but consider that it does not always meet all their healthcare needs.

Perceptions of Conventional Healthcare Providers and Community Leaders

Healthcare workers at the health centers confirmed that they occasionally received patients who had previously sought traditional medical care, although they believed that these cases were not always disclosed.

> *"Many parents do not tell us that they first saw a traditional healer, perhaps because they are afraid of being reprimanded," explained one nurse.*

Nevertheless, healthcare workers reported receiving some patients late, with complications. Examples included:

> *"A case of measles that had initially been treated with herbal decoctions, or a severely malnourished child brought to the hospital after a lot of time had been lost with a traditional practitioner."*

According to the healthcare workers, families generally turned to the CHC after "failure of traditional treatment."

Healthcare providers partly understood the initial preference for TPPs, citing the same economic and cultural factors mentioned by mothers: cost, proximity, and customs.

They also recognized that formal health-system coverage remains insufficient, particularly in disadvantaged urban settings where entire neighborhoods may be far from a CHC, contributing to the widespread presence of herbalists in markets.

When asked about possible collaboration with traditional practitioners in the management of malnutrition, healthcare workers expressed cautious support.

Several emphasized that community outreach workers and CHWs already exist and could incorporate trained traditional healers:

> *"If we train these traditional practitioners to measure MUAC and recognize danger signs, they could screen children in their neighborhoods and refer malnutrition cases earlier."*

One healthcare worker recalled that, during a previous government initiative for integration under a former Minister of Health, joint training sessions had been organized with traditional practitioners on malaria and diarrhea. According to him:

> *"It created a climate of trust, and they referred more complicated cases to us than before."*

However, healthcare workers emphasized the need for clear protocols and follow-up:

> *"There would need to be some kind of referral form, a way of tracking the cases they identify, and ensuring that they do not administer inappropriate remedies that delay treatment."*

They were particularly concerned about diagnostic errors, such as interpreting nutritional edema associated with kwashiorkor as having a mystical cause, and about inadequate dosing of traditional treatments.

One physician suggested:

> *"We could formalize a two-way referral system: the TPP identifies and refers a malnourished child to the CHC with a referral note, and after stabilization, the health center could return the child to the community for follow-up, with dietary counseling based on locally available foods."*

The concept of returning stabilized children to the community with the support of trained traditional practitioners is potentially valuable, but it would require national guidelines to become operational.

Community leaders consulted - including members of community health associations and local notables - strongly supported involving traditional practitioners in nutrition activities.

They themselves recognized the importance of cultural beliefs:

"In our community, many people believe that certain illnesses such as "Kono" [severe malnutrition] are caused by djinns or sorcerers/witches, so they go to the healer to remove the spell."

They believed that combating malnutrition requires household nutrition education and that traditional healers could contribute because:

"People listen to them in the community."

Some leaders suggested organizing educational sessions involving both healthcare workers and traditional practitioners, for example in mosques after prayers or during women's meetings, to teach appropriate infant and young child feeding practices, including exclusive breastfeeding for six months, dietary diversification, and avoidance of excessively diluted foods.

They also emphasized the importance of promoting nutritious local recipes:

"Our women no longer know how to prepare bènèdèn [a fortified porridge made from millet, peanuts, and cowpeas]. We need to teach them again with the help of grandmothers and herbalists."

Several cited "tigadéné ni muso," a traditional fortified porridge, which they considered comparable to Plumpy'Nut in effectiveness, as well as mixtures of cereal flour and peanut paste historically used during the lean season.

These traditional food practices could potentially be rehabilitated for malnutrition prevention, with support from community leaders and traditional practitioners.

Finally, community leaders noted that communities had already undertaken activities such as home visits by volunteers or community outreach workers to identify children who were becoming wasted and advise their parents.

According to them, formally involving TPPs and herbalists in these efforts would strengthen families' trust in prevention messages and help overcome cultural barriers:

"If the respected traditional practitioner tells the mother to go to the health center for nutrition care, she will go."

They therefore called for official collaboration in which each party would retain its defined role while supporting the other.

Nutritional Status of Children Consulting Traditional Practitioners

Among the 302 children aged 6 - 59 months measured at traditional practitioner sites, anthropometric findings revealed a significant prevalence of malnutrition in this consulting population.

Based on weight-for-height (WHZ) using WHO growth standards, combined with assessment for edema, 15.8% of children presenting to TPPs had global acute malnutrition (GAM), including 6.0% with severe acute malnutrition (SAM).

Although indicative, these rates are high. For comparison, national GAM prevalence was estimated at approximately 7 - 9% in 2020.

This suggests that children presenting to traditional practitioners are often already in a vulnerable health condition, with malnutrition potentially underlying their other illnesses.

Girls and boys were affected at similar levels, with no statistically significant difference in GAM prevalence by sex in our sample.

Nearly all cases of acute malnutrition detected were cases of marasmus, characterized by severe wasting without edema. No clear case of kwashiorkor, defined by nutritional edema, was observed in the field, although some mothers reported swollen feet that were subsequently diagnosed as kwashiorkor at the hospital.

Using the simple MUAC indicator with a threshold of <125 mm, the prevalence of acute malnutrition was 4.5% among these children, including 0.7% with severe acute malnutrition defined by MUAC < 115mm.

The lower prevalence compared with WHZ is explained by the fact that many children with moderate wasting had MUAC values just above 125 mm, corresponding to the borderline or "yellow" zone, while still being classified as wasted according to WHZ.

This illustrates the limitations of MUAC-only screening for borderline cases. Nevertheless, MUAC remains a practical tool and, in this setting, allowed rapid identification of a proportion of children at nutritional risk.

These 4.5% of children presenting with red or markedly yellow MUAC measurements should have been referred to a nutrition treatment program. However, outside our measurement intervention, they would probably not have been identified because neither mothers nor traditional practitioners routinely measured MUAC before our training.

Furthermore, height-for-age demonstrated that 14.2% of children seen by TPPs suffered from chronic malnutrition, or stunting (height-for-age z-score <−2 SD).

This stunting prevalence was somewhat lower than the national urban average, estimated at approximately 20–25%, which may be explained by selection bias. Our sample included a large proportion of infants younger than 18 months: 53% of children were aged 6–17 months, whereas stunting generally becomes more apparent after two years of age.

Indeed, age-specific analysis showed that younger children aged 6–17 months were less affected by stunting, with approximately 8% having moderate stunting and 2% severe stunting, compared with children aged 18–29 months, among whom severe stunting reached approximately 13% and moderate stunting 18%.

This pattern is consistent with national trends in which chronic malnutrition increases with age, reflecting repeated nutritional deficiencies after the introduction of inadequate complementary foods.

Boys appeared slightly more affected by stunting than girls in our sample (18.8% versus 9.9%, respectively), a difference consistent with national statistics, which generally show somewhat higher malnutrition rates among boys.

The reasons for this disparity remain unclear but may involve biological or sociocultural factors. For example, in some societies girls may receive slightly better nutrition or protection, while boys may be more susceptible to infections contributing to undernutrition.

Regarding overweight, approximately 3% of children seen by TPPs were overweight (WHZ > +2 SD), including 0.7% who were obese (WHZ > +3 SD).

These proportions remained low and were concentrated among younger children, including a few infants under two years of age who were relatively plump. Overweight was therefore not a major concern in this cohort compared with acute malnutrition.

In summary, the anthropometric findings confirm that traditional practitioners frequently receive children who, beyond their apparent acute illnesses such as malaria or diarrhea, have underlying malnutrition.

Without systematic nutritional screening, these children may fail to receive appropriate nutritional care, potentially compromising their overall recovery.

Our study also indicates that the weight-for-height distribution among consulting children was clearly shifted to the left compared with WHO reference standards, suggesting that this population was generally thinner and more nutritionally vulnerable.

This finding underscores the importance of integrating nutritional screening into every consultation, including traditional medical consultations.

Discussion

The findings of this exploratory study demonstrate a real opportunity for integration between traditional and conventional medicine to improve the management of childhood malnutrition in Mali. On the one hand, traditional pediatric practitioners receive large numbers of sick children every day for conditions similar to those treated in health centers, particularly common childhood infectious diseases. They therefore represent a key point of contact for the population, often before any contact with the formal health system. On the other hand, we found that a substantial proportion of children brought to traditional healers suffer from acute malnutrition that is generally not recognized as such. This finding is consistent with observations from other countries. For example, a recent qualitative study in Ethiopia found that parents of malnourished children frequently sought care from traditional healers, partly because they did not recognize malnutrition as a distinct disease and attributed its manifestations to traditional causes [2]. Our findings confirm that many mothers describe "loss of appetite" or "weakness" without linking these symptoms to the biomedical concept of malnutrition and therefore turn to TPPs for these problems. Strengthening early detection through traditional practitioners could therefore address an important weakness in the current system.

Training traditional healers to measure MUAC and recognize nutritional edema could increase the likelihood that malnourished children are detected and referred earlier to appropriate services. The example of neighboring Niger is particularly informative. In the Zinder region, the NGO GOAL trained more than 350 traditional healers and volunteer mothers in MUAC screening, enabling approximately 15,000 malnourished children to receive treatment within only 18 months through an expanded community-based network [16]. One Nigerien traditional healer who subsequently became a community health worker reported that, before receiving training, he "saw many children with signs of malnutrition without recognizing them" and attempted to treat them with herbs for presumed evil spirits [16]. After learning to detect nutritional edema and use MUAC, he was able to save his own daughter and ultimately refer 13 children from his village to the nutrition center [16].

This account illustrates the potential impact of such integration: once traditional practitioners understand malnutrition and are appropriately equipped, they can become valuable allies in referral and community education rather than parallel providers operating in isolation. The diagnostic performance of mid-upper arm circumference (MUAC) alone should, however, be interpreted with caution. A meta-analysis of studies conducted in African settings reported that MUAC had limited sensitivity (38.1%), despite high specificity (94.9%), for the detection of acute malnutrition when compared with weight-for-height (WHZ). This finding is consistent with our own observations, whereby the prevalence of acute malnutrition identified using MUAC (4.5%) was substantially lower than that identified using weight-for-height (15.8%) in our study sample [17]. Accordingly, training traditional medicine practitioners to rely solely on MUAC for nutritional screening may result in a substantial proportion of children with moderate acute malnutrition being missed. MUAC-based screening should therefore ideally be complemented by training in the recognition of other clinical signs, including bilateral pitting oedema and visible wasting, together with systematic referral of children presenting with suspected malnutrition or for whom diagnostic uncertainty remains or whenever there is any doubt. Our study also highlights factors that could facilitate or hinder this collaboration.

Enabling Factors

Traditional practitioners were generally receptive to referring cases beyond their capacity to manage. They already do so, particularly for severe malaria. They recognize their material limitations, including the absence of therapeutic foods, and are willing to cooperate when this serves the child's best interests. Their enthusiastic participation in the brief MUAC training we provided is an encouraging sign. The population, for its part, has a high level of trust in traditional practitioners. If traditional practitioners incorporate malnutrition screening into their routine practices, mothers are likely to accept this approach readily. Indeed, the mothers interviewed overwhelmingly stated that they would follow the advice of a TPP, even if the practitioner advised them to go to the hospital. Traditional authority could therefore serve as a trusted bridge to increase utilization of nutrition services, particularly where an unfamiliar health worker might be ignored. Malian health authorities have also demonstrated a relatively progressive attitude toward traditional medicine [6, 18]. Existing institutions, including MFTTH and the Department of Traditional Medicine, provide structures that could support the development of national guidelines involving traditional practitioners in nutritional screening and prevention. The regulatory environment is therefore relatively favorable compared with that of some other countries.

Challenges

Nevertheless, several challenges must be addressed for integration to be effective and beneficial. The first challenge concerns harmonizing knowledge and concepts.

As highlighted by the Ethiopian study [2], there is a gap between conventional healthcare providers and traditional healers in their understanding of what malnutrition is, its causes, and its treatment. Among Malian traditional practitioners, malnutrition is often attributed to temporary feeding disorders or mystical influences and treated with appetite-stimulating plants rather than through a comprehensive nutritional approach. A substantial investment in training and dialogue will therefore be necessary to establish a common vocabulary. For example, in Bambara, malnutrition could be explained simply as:

“The child is too thin because he is not eating enough or is not digesting properly, and this weakens his body. He therefore needs a special food to help him to regain weight and recover”. Traditional practitioners need to understand the life-saving role of RUTF and fortified foods without necessarily rejecting their own traditional knowledge. One possible approach would be to work with them to identify locally available nutrient-rich plants or food preparations that could be incorporated into complementary feeding. Another major issue is preserving complementarity and avoiding situations in which children are transferred between providers or experience delays in receiving appropriate treatment.

Ideally, a bidirectional referral system should be established: the TPP identifies and rapidly refers children with SAM or medical complications to the health center, and the health center, after stabilization, returns the child to the community for follow-up, including food distribution and weekly MUAC monitoring, potentially supported by a trained TPP. For this to work, communication must be effective through referral forms, telephone communication, or other mechanisms.

Currently, the lack of feedback may discourage traditional practitioners from making referrals because they do not know whether “their” patients received appropriate treatment. CHC healthcare providers, meanwhile, may be suspicious of traditional practitioners if they perceive them as competitors or as sources of treatment delays. These mutual concerns will need to be addressed through joint workshops, mutual respect, and clearly defined roles. The

management of moderate acute malnutrition also requires consideration.

Even within Mali's conventional health system, moderate acute malnutrition is inadequately covered, with active treatment often focused primarily on SAM. Involving traditional practitioners could provide an opportunity to extend MAM management to the community level, potentially using a single therapeutic food product such as the OptiMA approach. However, this would require addressing RUTF supply constraints, as these products are currently imported and expensive, as well as ensuring appropriate supervision and use.

Another option would be to explore locally available solutions for MAM.

Traditional practitioners and local women possess knowledge of nutritious recipes, including fortified flours and peanut-soy porridges. Studies in Benin have documented numerous plants and mixtures traditionally used to manage childhood malnutrition [19].

These remedies could be scientifically evaluated and, if demonstrated to be effective and safe, promoted as supplements for prevention or MAM management, thereby reducing dependence on expensive imported products. It should be recalled that, in conventional programs, treatment costs are substantially driven by RUTF, which may account for up to 50–70% of the cost per child [20, 21]. Mobilizing validated local nutritional resources could therefore improve financial sustainability.

Finally, the involvement of traditional practitioners should be embedded within a broader strategy to strengthen the community health system. Traditional practitioners should work closely with community health workers and community outreach workers already operating in the system. These existing actors cover villages and neighborhoods through various activities, including malaria screening and child growth-monitoring visits.

Traditional practitioners should not replace them but rather complement them by reaching families that even community outreach workers may not reach—particularly families who rely exclusively on traditional healthcare pathways. Local coordination under the leadership of the CHC, bringing together all community-based actors, will be essential to prevent duplication and clarify roles. For example, a community outreach worker could accompany a trained TPP during a screening session at a weekly market.

Conclusion

This study conducted in the Bamako District provides new insight into potential linkages between traditional medicine and the management of malnutrition. Traditional practitioners emerged as highly utilized first-line healthcare providers who enjoy substantial community trust and accessibility that the formal health system does not always provide. We demonstrated that many malnourished children pass through their care without being identified as malnourished, representing missed opportunities for early referral to appropriate services.

Involving traditional healers in the fight against malnutrition through MUAC screening, nutrition education, and potentially community-based management of MAM could substantially improve coverage of nutrition interventions and contribute to an earlier and more integrated response to acute malnutrition.

Nevertheless, rapprochement between the two medical systems must be pursued rigorously and collaboratively. Traditional practitioners should be trained in the fundamentals of nutrition and modern clinical criteria without devaluing their traditional knowledge. This would enable them to become informed partners capable of recognizing their limitations and working collaboratively with health services.

Formal referral and follow-up mechanisms should be established and supported by health

authorities and traditional practitioner associations. Successful experiences elsewhere in Africa, including Niger and Ethiopia, together with Mali's longstanding commitment to integrating traditional medicine, provide encouraging conditions for such an approach.

In summary, integrating traditional practitioners, practices, and products into nutrition activities is neither a step backward nor a magical solution to cure-all (a magical cure-all). Rather, it represents an additional strategy or tool for reaching the most vulnerable children while respecting the local sociocultural context.

Our preliminary findings support the feasibility of this approach and encourage progression to the operational phase - Phase 2 of the research - in which these concepts will be implemented and quantitatively evaluated in terms of their impact on the detection and recovery of malnourished children.

If successful, such an innovation could serve as a model for other settings in West and Central Africa where malnutrition remains endemic and where health systems could benefit from engaging traditional actors for the benefit of communities.

Study Limitations

Several methodological limitations should be considered when interpreting these preliminary findings. First, this was an exploratory qualitative study based on a convenience sample. The sample size was not determined a priori according to a predefined criterion of theoretical data saturation; rather, it was determined by the number of mothers attending traditional medicine practitioner (TMP) sites during the data collection period.

Second, mothers were recruited exclusively from traditional medicine practitioners' places of practice, introducing an evident selection bias. Consequently, our sample may overrepresent families already engaged in the use of traditional medicine, and the findings cannot be generalized to all children in Bamako. The absence of a comparison group recruited from community health centres (CHCs) precludes determining whether the observed prevalence of malnutrition actually differs from that among children receiving care exclusively through the conventional healthcare system.

Finally, in the absence of a control or comparison group and longitudinal follow-up, this study cannot establish a causal relationship between the use of traditional medicine and children's nutritional status. Rather, it documents an association and reported perceptions at a specific point in time, within a particular urban context, thereby limiting the transferability of the findings to other regions of Mali, particularly rural settings.

Conflict of Interest

The author declares that there are no conflicts of interest related to this study. Every effort was made to ensure impartiality and objectivity throughout the research, data analysis, manuscript preparation and reporting processes.

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Ethical Approval

This study received ethical approval from the Ethics Committee of the the Malian Federation of Traditional Therapists and Herbalists (MFTTH), which issued a favorable opinion (Prot. N° 01-10-04-2020/SG). Authorization was also obtained from the relevant local health authorities to conduct data

collection within the participating health areas (Prot. N°01-02-11/2019-RS].

All study procedures were conducted in accordance with national guidelines governing research involving human participants. Written informed consent was obtained from all participants prior to enrolment in the study. Participant confidentiality and anonymity were strictly maintained throughout the study. The Malian Federation of Traditional Therapists and Herbalists (MFTTH),

Authors' Contributions

All authors contributed to the conduct of this work. All authors reviewed and approved the final manuscript.

Data Availability

The datasets generated and analyzed during the current study are not publicly available due to ethical and confidentiality restrictions. However, they are available from the corresponding author upon reasonable request and subject to approval by the Ministry of Health of Mali.

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