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From Interoperability to Impact: Evaluating the Effect of Digital Health on Population Reach and Service Utilization in Zambia

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Abstract

Digital health systems are increasingly recognized as strategic enablers of health system strengthening and Universal Health Coverage (UHC) in low- and middle-income countries. However, limited empirical evidence exists regarding whether digital health transformation initiatives produce measurable population-level health system outcomes. This study evaluates Zambia's national digital health transformation by examining the effect of interoperability, governance, and integrated electronic health record systems on population reach, demographic utilization, and health service delivery outcomes. An implementation science case study approach was employed using a national SmartCare Pro dataset comprising more than 12.5 million client records. Additional data sources included interoperability reports, Ministry of Health strategic frameworks, governance instruments, and digital health policy documents. Descriptive statistical analysis was conducted across population reach, demographic distribution, healthcare utilization, and system-level operational outcomes. Findings demonstrate that SmartCare Pro achieved substantial national digital health coverage across all provinces in Zambia. Female utilization accounted for 58.8% of registered clients, while Lusaka, Southern, and Copperbelt provinces collectively accounted for more than 53% of all registrations. Interoperability between SmartCare Pro and logistics management systems improved prescription-to-dispensing linkage, medicine stock visibility, supply chain forecasting, continuity of care, and evidence-based planning. The study demonstrates that governance-driven interoperable digital health ecosystems can generate measurable health system outcomes beyond technical implementation indicators. Zambia's digital health transformation provides an important implementation model for low- and middle-income countries seeking to strengthen healthcare systems through integrated digital ecosystems capable of supporting healthcare delivery, national health intelligence, and population-level decision-making.

Keywords: *Digital Health, Electronic Health Records, Health Systems Strengthening, Interoperability, SmartCare Pro, Universal Health Coverage, Zambia.*

Introduction

Digital transformation has become a central pillar of healthcare modernization globally, with governments increasingly recognizing digital health technologies as essential components for improving healthcare delivery, strengthening health systems, and achieving Universal Health Coverage (UHC) [1]. The World Health Organization (WHO) defines digital health as the use of information and communication technologies to improve health outcomes, healthcare services, health system management, and public health interventions [1]. Digital health interventions include electronic health records (EHRs), telemedicine systems, mobile health applications, interoperability platforms, health analytics

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systems, artificial intelligence tools, and digital disease surveillance systems.

In low- and middle-income countries (LMICs), digital health transformation is increasingly viewed as a strategic mechanism for addressing persistent health system challenges such as workforce shortages, weak health information systems, fragmented service delivery, poor continuity of care, and inefficient resource allocation [2]. Many African countries continue to experience substantial disparities in healthcare access, limited infrastructure, poor referral systems, and delayed reporting mechanisms that compromise healthcare quality and responsiveness [3].

Historically, health information systems in sub-Saharan Africa were characterized by paper-based reporting systems that resulted in delays in data transmission, poor data quality, duplication of records, and limited ability to support evidence-based planning [5]. The emergence of digital health systems introduced opportunities to improve healthcare coordination, strengthen data-driven planning, and enhance population-level health intelligence [4].

Despite the promise of digital health technologies, implementation across Africa has often been fragmented and donor-driven [13]. Multiple standalone systems were introduced independently across disease programs and healthcare institutions, resulting in duplication, weak interoperability, parallel reporting structures, and limited national ownership [5]. Many countries lacked national governance frameworks and interoperability standards capable of coordinating digital health implementation across institutions and partners [6].

Interoperability has therefore emerged as a critical component of digital health transformation. Interoperability enables health information systems to exchange, interpret, and utilize data across platforms and healthcare settings [6]. Without interoperability, health systems risk developing isolated digital silos that undermine continuity of care and limit the utility of health information systems for strategic planning and healthcare management.

Recognizing these challenges, Zambia initiated a national digital health transformation agenda aimed at establishing an integrated, interoperable, and governance-driven digital health ecosystem. The transformation was guided by several strategic policy instruments, including:

1. National Digital Health Strategy (2022–2026).
2. Interoperability Architecture Framework.
3. Health Data Governance Framework.
4. National e-Government Strategy.
5. National Health Strategic Plan.

Central to Zambia's digital health ecosystem is the SmartCare Pro electronic health record system. SmartCare Pro supports patient-level data capture and service delivery across multiple healthcare programs and institutions. The system integrates with supply chain management systems, analytics environments, and health information exchange platforms to support continuity of care and integrated healthcare management.

Zambia's digital health transformation differs from many previous African digital health initiatives because of its strong emphasis on governance, interoperability, national ownership, and integrated health intelligence systems [7, 8]. The country adopted a government-led approach to digital transformation that prioritized standardization, scalability, interoperability, and long-term sustainability.

Previous evaluations of Zambia's digital health ecosystem primarily focused on technical implementation indicators such as interoperability compliance, governance maturity, and infrastructure deployment [18]. While these evaluations demonstrated progress in system integration and policy development, limited empirical evidence existed regarding whether these reforms translated into

measurable population-level health system outcomes.

This study therefore seeks to evaluate the impact of Zambia's digital health transformation by examining how SmartCare Pro and associated interoperability frameworks contribute to:

1. Population reach and digital health coverage.
2. Demographic utilization patterns.
3. Healthcare service utilization.
4. Health system strengthening.
5. Data-driven decision-making.
6. Continuity of care.
7. Supply chain efficiency.
8. National health intelligence.

The study further explores how governance and interoperability frameworks influence digital health implementation outcomes within a real-world healthcare environment.

By shifting analytical focus from technical implementation toward measurable health system outcomes, the study contributes to the growing body of implementation science literature examining the effectiveness of digital health transformation in LMICs.

Literature Review

Digital Health and Health System Strengthening

Digital health technologies are increasingly recognized as foundational tools for strengthening healthcare systems and improving service delivery [1]. Health information systems support patient management, healthcare coordination, disease surveillance, and evidence-based planning. EHR systems in particular improve continuity of care by enabling healthcare providers to access patient information across service delivery points [14].

The WHO Global Strategy on Digital Health emphasizes that digital technologies can contribute significantly to achieving UHC through improved access, efficiency, responsiveness, and patient-centered healthcare delivery [1]. Digital systems also support real-time reporting and public health surveillance, which are essential for responding to outbreaks and emerging health threats.

Several studies demonstrate that digital health systems improve healthcare quality through enhanced data availability, reduced duplication, and improved clinical decision-making [4]. However, the effectiveness of digital transformation depends heavily on governance, interoperability, financing, infrastructure, and workforce capacity [15].

Interoperability in Digital Health Systems

Interoperability refers to the ability of different health information systems to exchange and use data seamlessly across institutions and platforms [6]. Interoperability is increasingly viewed as essential for integrated healthcare delivery because patients frequently access services across multiple healthcare settings.

Open standards such as HL7 FHIR and OpenHIE architectures have become important frameworks for supporting interoperability in LMICs [19]. These standards allow systems to exchange patient information while maintaining data consistency and continuity of care.

Several African countries have struggled with fragmented digital ecosystems characterized by isolated systems operating independently [5]. Weak interoperability limits healthcare coordination, contributes to duplication, and reduces the ability of governments to utilize digital data for planning and decision-making.

Zambia's interoperability architecture framework represents an important national effort to standardize digital health integration and improve healthcare coordination through shared data systems.

Governance and Digital Transformation

Governance frameworks provide the institutional structures required to coordinate digital health implementation, regulate standards, ensure accountability, and maintain data quality [7]. Effective governance strengthens sustainability and national ownership while reducing fragmentation.

Countries lacking governance frameworks often experience inconsistent implementation approaches and unsustainable donor-driven digital ecosystems [13]. Governance also plays an important role in ensuring data privacy, ethical management of health information, and alignment between digital investments and national priorities.

Zambia's governance-driven approach demonstrates how policy frameworks can support coordinated digital transformation and national integration.

Digital Health in Africa

Across Africa, digital health initiatives have expanded significantly over the past decade [9]. Mobile health applications, disease surveillance systems, EHRs, and telemedicine platforms are increasingly utilized to improve healthcare accessibility and efficiency.

However, infrastructure challenges remain substantial. Rural facilities often experience limited electricity, poor internet connectivity, insufficient digital equipment, and workforce shortages [12]. These challenges contribute to uneven implementation and disparities in healthcare access.

Studies further indicate that sustainable digital transformation requires investments in infrastructure, workforce development, governance, financing, and interoperability [15]. Countries that successfully integrate these components are more likely to achieve measurable health system outcomes.

Methods

Study Design

This study employed an implementation science case study approach to evaluate Zambia's digital health transformation within its real-world healthcare delivery environment [16]. Implementation science is concerned with understanding how policies, technologies, and interventions are adopted, operationalized, scaled, and sustained within routine practice settings, particularly in complex health systems. Unlike traditional experimental research approaches that primarily focus on efficacy under controlled conditions, implementation science emphasizes practical functionality, contextual adaptation, operational performance, and system-level outcomes within real service delivery environments.

The implementation science approach was considered appropriate for this study because Zambia's digital health transformation represents a large-scale, multi-dimensional national intervention involving governance reforms, interoperability frameworks, electronic health record systems, infrastructure expansion, workforce engagement, and institutional coordination. These components interact dynamically across multiple levels of the healthcare system and therefore require evaluation approaches capable of assessing implementation processes and operational outcomes simultaneously.

A case study methodology was adopted because it enables in-depth examination of complex health system interventions within their natural operational context [17]. The case study design supports comprehensive exploration of interactions between digital technologies, institutional governance structures, health service delivery processes, healthcare workers, and population-level utilization outcomes. Furthermore, case study approaches are particularly useful in implementation science where interventions

cannot easily be isolated from the environments in which they operate.

The study specifically focused on Zambia's national digital health ecosystem between 2021 and 2025, a period characterized by accelerated digital transformation under the Ministry of Health's National Digital Health Strategy (2022–2026) [7]. During this period, the country implemented major interoperability and governance reforms aimed at strengthening integration between electronic health systems, improving continuity of care, enhancing national health intelligence, and supporting evidence-based healthcare decision-making.

The implementation science framework for this study examined how interoperability and governance structures influenced operational health system outcomes, including:

1. Expansion of population-level digital health coverage.
2. Demographic utilization patterns.
3. Continuity of care across service delivery points.
4. Integration of electronic health records with logistics systems.
5. Improvement in healthcare coordination and decision-making.
6. Enhancement of supply chain visibility and forecasting.
7. Strengthening of data-driven planning and national health intelligence.

The study further assessed how digital health technologies functioned within routine healthcare environments characterized by varying infrastructure capacity, workforce availability, internet connectivity, and healthcare utilization patterns. This was important because implementation outcomes in LMIC settings are often heavily influenced by contextual operational factors such as electricity reliability, digital literacy, staffing levels, institutional leadership, and governance maturity.

The implementation science approach also enabled examination of scalability and sustainability considerations associated with Zambia's digital health transformation. Rather than focusing exclusively on technical system functionality, the study explored broader health system implications including governance effectiveness, interoperability maturity, healthcare service integration, and policy alignment. This allowed the research to evaluate digital health transformation not merely as a technological intervention, but as a comprehensive health system strengthening strategy.

Additionally, the case study approach facilitated triangulation of multiple sources of evidence, including national SmartCare Pro datasets, interoperability system reports, policy frameworks, governance documents, and operational implementation reports. The use of multiple data sources strengthened the validity of findings and enabled a more comprehensive understanding of how digital health reforms translated into measurable population-level outcomes.

The design further allowed assessment of implementation outcomes across different geographic and demographic contexts within Zambia, including urban and rural settings, thereby providing insight into equity, access, and scalability challenges associated with national digital health deployment. This was particularly important in understanding disparities in digital health utilization and infrastructure readiness across provinces.

Overall, the implementation science case study design provided a robust framework for evaluating the transition from digital system implementation toward measurable health system impact. The approach enabled assessment of not only whether Zambia's digital health systems were operational, but also whether they contributed meaningfully to healthcare delivery, service utilization, continuity of care, and national health system strengthening.

Study Setting

The study was conducted within Zambia's national healthcare system, which operates under the Ministry of Health and provides healthcare services through a decentralized multi-tier service delivery structure. The healthcare system consists of tertiary hospitals, provincial hospitals, district hospitals, first-level hospitals, health centres, health posts, and community-based healthcare facilities distributed across all ten provinces of the country. These facilities collectively provide preventive, promotive, curative, rehabilitative, and public health services to the population.

Zambia's healthcare delivery system serves both urban and rural populations, with healthcare services organized through provincial and district health management structures. Urban provinces such as Lusaka and Copperbelt generally possess stronger infrastructure, higher population density, and greater access to specialized healthcare services, while rural provinces continue to experience challenges related to infrastructure, workforce shortages, internet connectivity, electricity supply, transportation, and healthcare accessibility.

The country has undergone significant digital health transformation between 2021 and 2025 through implementation of the National Digital Health Strategy (2022–2026), which prioritized development of interoperable digital health systems, strengthening of governance structures, and establishment of integrated health information platforms [7]. The transformation aimed to improve continuity of care, health intelligence, service delivery coordination, disease surveillance, and evidence-based healthcare planning.

Central to this transformation is the SmartCare Pro electronic health record (EHR) platform, which has been deployed across multiple healthcare facilities nationwide. SmartCare Pro serves as the national patient-level electronic health record system and supports healthcare service delivery across various disease programs and service areas, including:

1. HIV and AIDS services.
2. Maternal and child health services.
3. Outpatient and inpatient care.
4. Tuberculosis services.
5. Chronic disease management.
6. Pharmacy and dispensing services.
7. Laboratory and diagnostic services.
8. Public health surveillance and reporting.

SmartCare Pro enables healthcare providers to capture, retrieve, and manage patient information electronically, thereby improving continuity of care and reducing reliance on paper-based systems. The system supports patient tracking across service delivery points and contributes to integrated healthcare management through centralized data capture and reporting.

The digital health ecosystem in Zambia also includes interoperability platforms and integrated health information exchange mechanisms that facilitate communication between SmartCare Pro and other national health systems. These integrations support linkage with logistics management systems, national analytics platforms, disease surveillance systems, insurance systems, and aggregate reporting environments such as DHIS2.

The study setting was particularly appropriate for evaluating digital health transformation because Zambia represents one of the few LMIC contexts in sub-Saharan Africa that has implemented a nationally coordinated interoperability and governance-driven digital health strategy. The healthcare system therefore provided a suitable operational environment for assessing how digital health investments translate into measurable health system outcomes within routine healthcare delivery contexts.

The study further considered variations in healthcare utilization, infrastructure

availability, and digital system implementation across provinces and facility levels. These contextual differences provided important insights into equity, scalability, operational functionality, and digital health access within both urban and rural healthcare settings.

Data Sources

The study utilized multiple complementary data sources to provide a comprehensive assessment of Zambia's digital health transformation and its impact on population reach, healthcare utilization, and health system strengthening. The use of multiple data sources enabled triangulation of findings and improved the validity and reliability of the study outcomes.

National SmartCare Pro Dataset

The primary data source for the study was the national SmartCare Pro electronic health record dataset comprising more than 12.5 million client records collected across healthcare facilities nationwide. The dataset included anonymized patient-level information captured through routine healthcare service delivery processes and represented one of the largest integrated digital health datasets in sub-Saharan Africa.

The SmartCare Pro dataset provided information related to:

1. Patient registrations.
2. Demographic characteristics.
3. Age and sex distribution.
4. Provincial service utilization patterns.
5. Healthcare service encounters.
6. Healthcare utilization trends.
7. Continuity of care indicators.
8. Electronic prescription and dispensing records.

The dataset enabled population-level analysis of digital health utilization and supported assessment of demographic and geographic distribution patterns across Zambia's healthcare system.

Interoperability System Reports

Interoperability system reports were reviewed to assess integration between SmartCare Pro and other national health information systems. These reports included technical and operational documentation related to health information exchange platforms, interoperability frameworks, data exchange standards, and integration performance.

The interoperability reports provided insights into:

1. System integration maturity.
2. Prescription-to-dispensing linkage.
3. Data exchange functionality.
4. Integration with logistics management systems.
5. Continuity of care support mechanisms.
6. Real-time data synchronization processes.
7. National health intelligence integration.

These reports supported evaluation of how interoperability contributed to operational efficiency and integrated healthcare delivery.

Ministry of Health Policy and Strategy Documents

National policy and strategic documents developed by the Ministry of Health were reviewed to provide contextual understanding of Zambia's digital health transformation agenda. These documents included:

1. National Digital Health Strategy (2022–2026).
2. National Health Strategic Plan.
3. Health Data Governance Framework.
4. Interoperability Architecture Framework.
5. National e-Government Strategy.
6. Health information management policies.

The policy documents provided information regarding strategic priorities, governance structures, implementation objectives, digital

health standards, and national health system strengthening goals.

Digital Health Governance Frameworks

Governance frameworks and operational guidelines were reviewed to assess institutional arrangements supporting digital health implementation. These documents included governance policies, interoperability standards, data protection mechanisms, digital health coordination structures, and implementation guidelines.

The governance frameworks helped assess:

1. National ownership of digital systems
2. Governance maturity.
3. Standardization processes.
4. Data governance mechanisms.
5. Institutional coordination.
6. Sustainability frameworks.
7. Accountability structures.

National Health Information System Reports

National health information system reports were utilized to provide supplementary contextual information regarding healthcare service delivery, reporting systems, and national health intelligence processes. These reports supported interpretation of digital health utilization trends and healthcare system performance indicators.

Health System Implementation Documents

Additional implementation reports and operational documents related to digital health deployment, infrastructure expansion, system integration, and service delivery coordination were reviewed. These documents provided practical implementation insights regarding challenges, scalability, operational performance, and healthcare system integration processes.

Collectively, the combination of technical, operational, policy, and patient-level datasets enabled comprehensive evaluation of Zambia's digital health transformation and strengthened the robustness of study findings.

Data Analysis

Descriptive statistical analysis was employed to evaluate population reach, demographic distribution, healthcare utilization patterns, and system-level outcomes associated with Zambia's digital health transformation. The analytical approach focused on assessing operational health system impact rather than solely technical implementation metrics.

Data extracted from the SmartCare Pro national dataset were cleaned, aggregated, and analyzed to generate summary statistics and utilization patterns across provinces, demographic groups, and healthcare service categories. Analysis was conducted using frequency distributions, proportional analysis, demographic comparisons, and geographic distribution assessments.

The analytical process included:

1. Population-level registration analysis.
2. Sex-disaggregated utilization analysis.
3. Age-disaggregated demographic analysis.
4. Provincial distribution analysis.
5. Healthcare utilization trend analysis.
6. Interoperability outcome assessment.
7. System-level impact interpretation.

Frequency Distribution Analysis

Frequency distribution analysis was conducted to determine the volume and distribution of healthcare registrations captured within the SmartCare Pro system. This analysis enabled assessment of overall digital health coverage and healthcare utilization patterns across the national healthcare system.

The frequency analysis examined:

1. Total client registrations.
2. Provincial registration volumes.
3. Age group distribution.
4. Sex distribution.
5. Service utilization patterns.

Proportional Analysis

Proportional analysis was utilized to determine the relative contribution of

demographic groups and provinces to overall healthcare utilization. Percentage distributions were calculated to identify utilization disparities and demographic trends within the digital health ecosystem.

This analysis supported interpretation of:

1. Female versus male utilization.
2. Provincial healthcare concentration.
3. Age-related utilization trends.
4. Population coverage distribution.

Demographic Comparisons

Comparative demographic analysis was conducted to examine differences in healthcare utilization across sex and age categories. These comparisons enabled assessment of population engagement with healthcare services and identification of disparities in healthcare utilization patterns.

The demographic analysis also provided insight into maternal health utilization, reproductive health engagement, and age-related healthcare demand.

Provincial Analysis

Provincial analysis was conducted to assess geographic distribution of digital health utilization and identify disparities in healthcare access and infrastructure readiness across Zambia's provinces. Provincial comparisons enabled evaluation of digital health expansion and operational functionality within urban and rural contexts.

This analysis further highlighted variations in healthcare utilization associated with infrastructure availability, population density, and health system deployment maturity.

Interoperability and System Impact Analysis

Operational interoperability outcomes were assessed using interoperability reports and implementation documentation. Analysis focused on evaluating how system integration contributed to healthcare coordination, continuity of care, logistics management, and evidence-based planning.

Specific interoperability outcomes assessed included:

1. Prescription-to-dispensing linkage.
2. Reduction in duplication of records.
3. Medicine stock visibility.
4. Supply chain forecasting.
5. Data-driven decision-making support.
6. National health intelligence functionality.

Interpretation of findings was guided by established digital health evaluation frameworks and Universal Health Coverage indicators [1, 18]. The analytical approach emphasized understanding how governance and interoperability reforms translated into measurable operational and population-level outcomes within Zambia's healthcare system.

The use of descriptive analytical methods was considered appropriate because the study aimed to evaluate national implementation outcomes and health system functionality rather than establish causal experimental relationships. The analysis therefore focused on identifying trends, operational improvements, utilization patterns, and health system implications associated with Zambia's digital health transformation.

Ethical Considerations

Ethical approval was obtained through the Ministry of Health Zambia. All datasets utilized in the study were anonymized before analysis to ensure confidentiality and compliance with national data governance standards.

Results

Population Reach

SmartCare Pro achieved substantial national scale with 12,548,696 registered client records captured across all provinces in Zambia. This represents one of the largest integrated electronic health record datasets in sub-Saharan Africa and demonstrates significant progress toward universal digital health coverage.

The findings indicate that Zambia has successfully transitioned from fragmented

digital systems toward a nationally coordinated digital health ecosystem capable of supporting population-level health intelligence.

Gender Distribution

Gender-disaggregated analysis revealed that females accounted for 58.8% (7.37 million) of SmartCare Pro registrations, while males accounted for 41.2% (5.17 million), as shown in Figure 1.

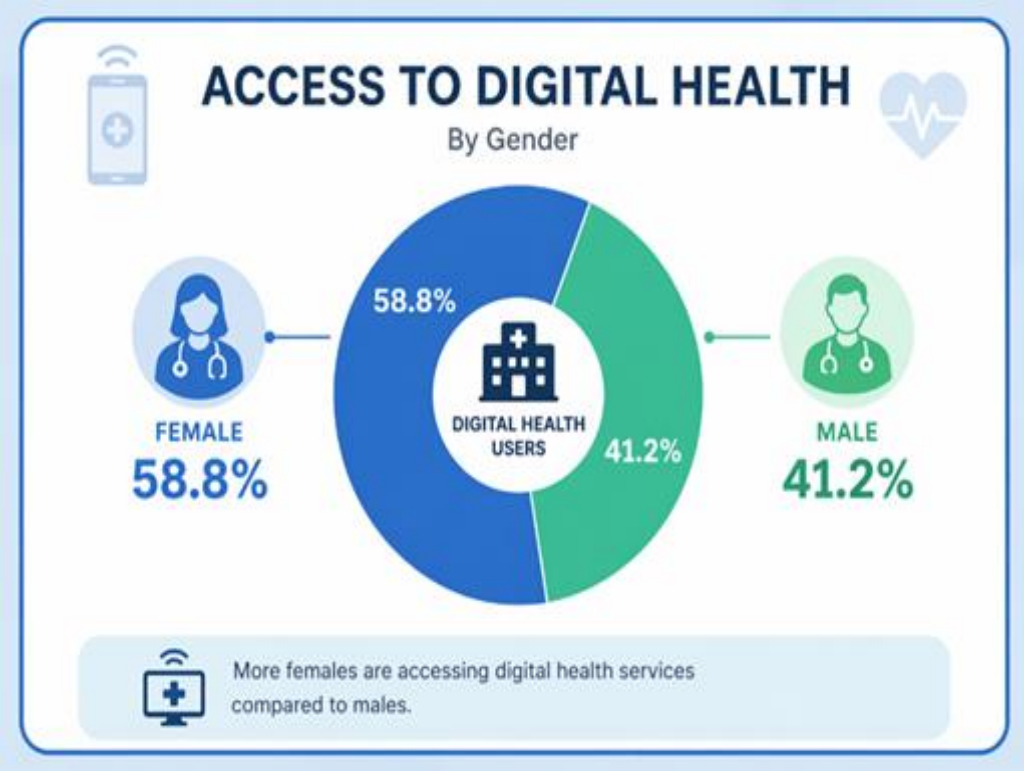


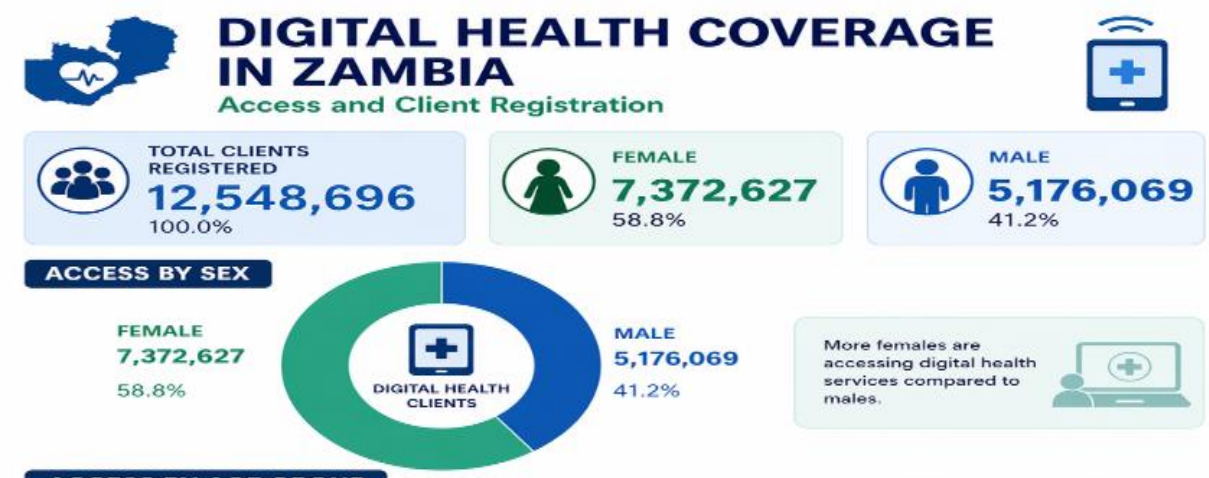
Figure 1. Gender Distribution of SmartCare Pro Clients

Higher female utilization reflects strong engagement in maternal, reproductive, and HIV-related healthcare services [10, 11]. However, the lower male utilization highlights persistent challenges in male healthcare engagement and health-seeking behaviour.

These findings suggest the need for targeted interventions aimed at increasing male participation in healthcare services and improving gender-balanced utilization patterns.

Provincial Distribution

The provincial distribution of SmartCare Pro registrations reflects uneven but strategically concentrated growth across Zambia's healthcare system. As shown in Figure 2, Lusaka, Southern, and Copperbelt provinces collectively account for more than 53% of total SmartCare Pro registrations.



ACCESS BY AGE GROUP

Age Group	Female n (%)	Male n (%)	Total n (%)
< 15 Years	1,447,880 (49.9)	1,454,816 (50.1)	2,902,696 (100.0)
15 - 24 Years	1,329,021 (60.1)	881,564 (39.9)	2,210,585 (100.0)
25 - 34 Years	1,815,124 (66.3)	922,965 (33.7)	2,738,089 (100.0)
35+ Years	2,780,602 (59.2)	1,916,724 (40.8)	4,697,326 (100.0)

ACCESS BY PROVINCE

Province	Female n (%)	Male n (%)	Total n (%)
Central	417,629 (58.0)	302,658 (42.0)	720,287 (100.0)
Copperbelt	1,031,318 (57.6)	760,239 (42.4)	1,791,557 (100.0)
Eastern	737,169 (58.3)	527,290 (41.7)	1,264,458 (100.0)
Luapula	264,215 (58.8)	185,191 (41.2)	449,406 (100.0)
Lusaka	1,727,145 (59.9)	1,158,578 (40.1)	2,885,723 (100.0)
Muchinga	215,156 (57.4)	159,908 (42.6)	375,064 (100.0)
North-Western	215,826 (58.7)	151,572 (41.3)	367,198 (100.0)
Northern	346,672 (59.1)	240,391 (40.9)	587,063 (100.0)
Southern	1,226,343 (58.4)	872,115 (41.6)	2,098,458 (100.0)
Western	289,784 (59.1)	200,395 (40.9)	490,179 (100.0)

Figure 2. Provincial Distribution of SmartCare Registrations

This distribution pattern is primarily influenced by;

1. Higher urban population concentration
2. Stronger digital and health infrastructure.
3. Greater healthcare utilization rates.
4. Increased availability of specialized healthcare services.
5. Improved internet connectivity and digital deployment readiness.

The findings demonstrate that provinces with stronger infrastructure and higher population density tend to experience faster digital health adoption and higher utilization of electronic health record services. However, the lower registration levels observed in some rural provinces highlight persistent disparities in healthcare access, infrastructure readiness, digital connectivity, and workforce distribution.

The provincial analysis further emphasizes the need for targeted investments in underserved regions to strengthen equitable digital health expansion and ensure nationwide access to integrated healthcare services.

Age Distribution

The age and sex distribution of registered clients is presented in Figure 3.

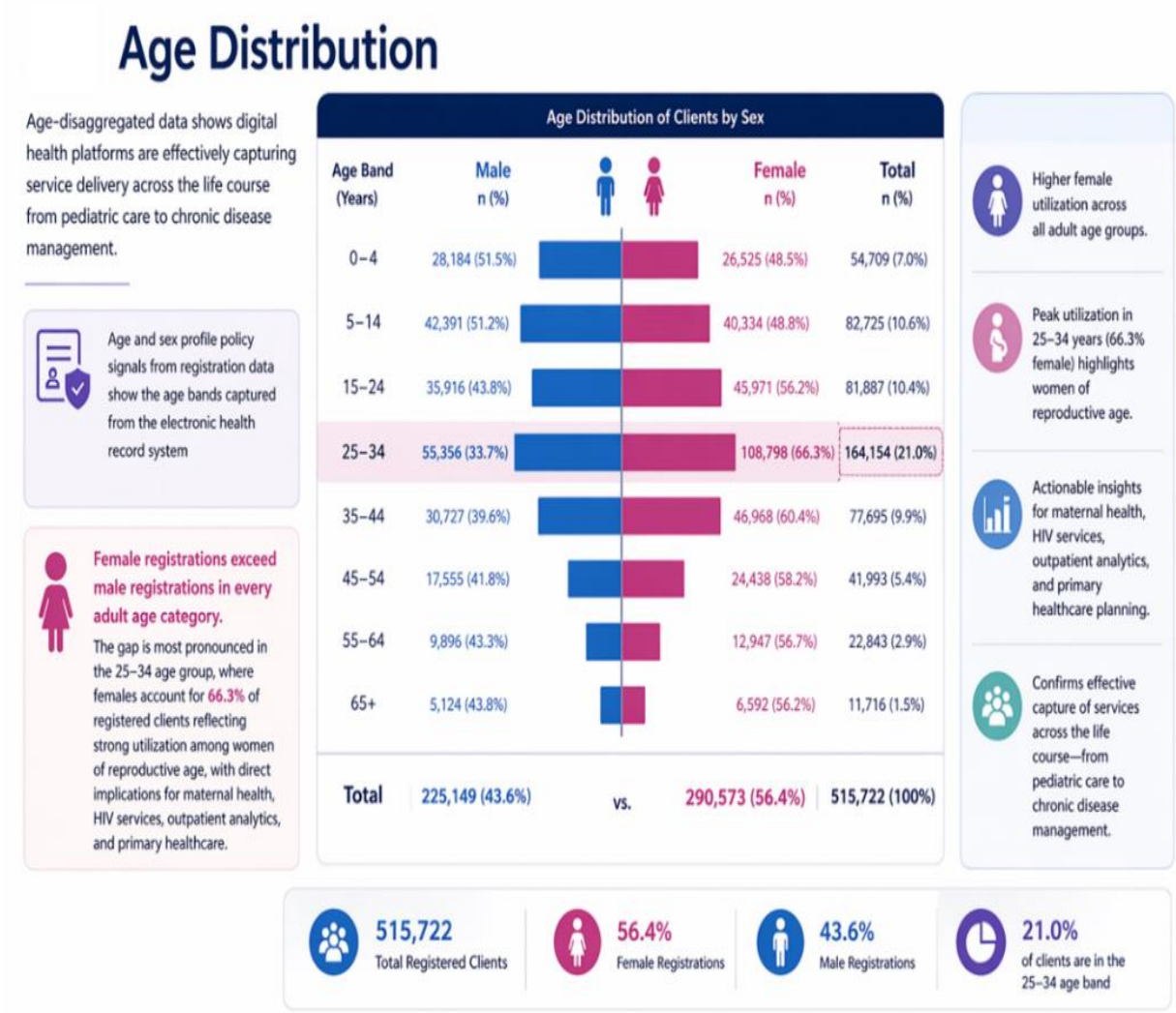


Figure 3. Age Distribution of Clients

The data demonstrate effective digital capture of healthcare utilization across the life course, ranging from pediatric care to chronic disease management among older populations.

Female registrations exceeded male registrations across all adult age categories, with the largest disparity observed among individuals aged 25–34 years, where females accounted for 66.3% of registrations. This trend reflects high utilization of reproductive health, maternal health, and HIV services among women of reproductive age.

Interoperability Impact

Integration of SmartCare Pro with the national logistics information management system through the Health Information Exchange (HIE) platform significantly strengthened interoperability across Zambia's healthcare ecosystem. The interoperability relationship and operational workflow are illustrated in Figure 4.

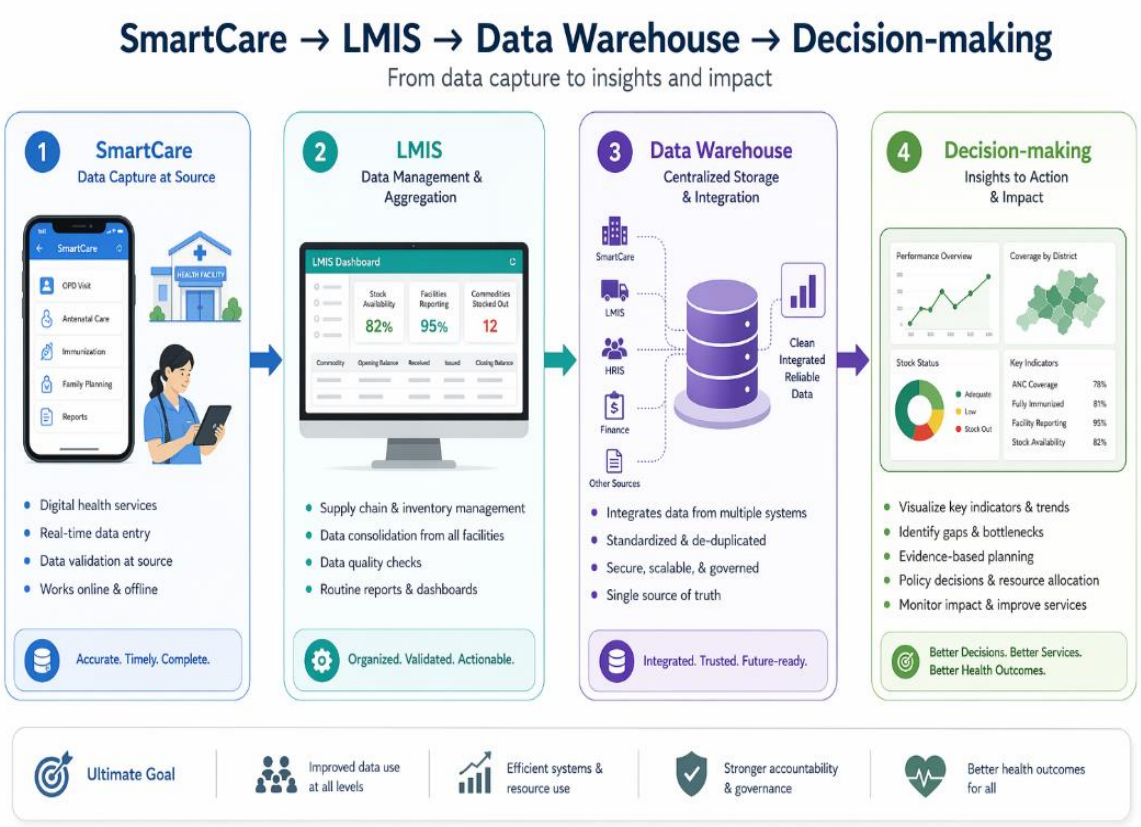


Figure 4. Interoperability Impact Pathway

The interoperability architecture enabled real-time exchange of patient-level information between clinical and supply chain systems, thereby improving healthcare coordination and operational efficiency. Key interoperability outcomes observed through the integrated ecosystem included:

1. Real-time prescription-to-dispensing linkage.
2. Improved medicine stock visibility across facilities.
3. Enhanced supply chain forecasting and commodity planning.
4. Reduction in duplication of patient records.
5. Improved continuity of care across service delivery points.
6. Strengthened national health intelligence and reporting.

The integration between SmartCare Pro and logistics systems demonstrates how interoperable digital platforms can improve both clinical service delivery and operational healthcare management simultaneously. These findings align with global digital health interoperability principles that emphasize integrated data exchange as a foundation for efficient and responsive healthcare systems [6, 19].

Furthermore, the interoperability framework contributed to evidence-based planning and strengthened the Ministry of Health's ability to monitor healthcare utilization patterns, medicine availability, and service delivery trends in near real-time.

Health System Strengthening Outcomes

The digital health ecosystem contributed to measurable improvements in:

1. Clinical decision-making.
2. Disease surveillance.
3. Data-driven planning.
4. Resource allocation.
5. Healthcare coordination.
6. National health intelligence.
7. Continuity of care.

The findings demonstrate that digital systems can contribute directly to health system strengthening when integrated within governance and interoperability frameworks.

Discussion

Transition from Technical Implementation to Population-Level Impact

The findings demonstrate that Zambia's digital health transformation successfully moved beyond technical implementation toward measurable population-level outcomes. Many LMIC digital health initiatives focus primarily on deployment metrics without evaluating actual healthcare impact.

In contrast, Zambia's approach emphasized integration, governance, and interoperability, enabling the health system to utilize digital data for operational and strategic decision-making.

Governance as a Foundation for Digital Transformation

Governance frameworks played a critical role in coordinating digital health implementation and reducing fragmentation. The National Digital Health Strategy and Interoperability Architecture Framework provided institutional direction for system integration and standardization.

This governance-driven approach contributed significantly to national ownership and sustainability.

Interoperability and Continuity of Care

Interoperability strengthened healthcare coordination by enabling data exchange between SmartCare Pro and logistics systems. Patients receiving care across multiple facilities benefited from improved continuity of care and reduced duplication.

Interoperability also improved medicine tracking and supply chain management, demonstrating the broader operational benefits of integrated digital ecosystems.

Gender and Health Service Utilization

The predominance of female utilization reflects successful engagement in maternal and reproductive health programs. However, lower male participation suggests continued barriers to healthcare utilization among men.

Policy interventions aimed at improving male health-seeking behaviour remain important.

Equity and Rural Access Challenges

Provincial disparities reveal persistent inequities in infrastructure and digital access. Rural provinces face ongoing challenges related to connectivity, electricity, workforce shortages, and digital infrastructure.

Addressing these disparities is essential for achieving equitable digital health coverage.

Implications for LMICs

Zambia's experience provides several lessons for LMICs:

1. Governance should precede technology deployment.
2. Interoperability is essential for integration.
3. National ownership improves sustainability.
4. Integrated systems strengthen decision-making.
5. Digital health investments should align with health system priorities.

Countries pursuing digital transformation should therefore adopt integrated, governance-driven approaches rather than fragmented standalone systems. Recent evidence further demonstrates that integrated digital ecosystems improve health system resilience, operational responsiveness, and continuity of healthcare delivery in resource-constrained settings [20].

Study Limitations

The study relied on secondary electronic health record data, which may not fully capture healthcare utilization outside digitized

facilities. Private sector healthcare data were also incompletely represented.

Additionally, provincial differences in infrastructure may influence registration patterns and service utilization trends.

Conclusion

Zambia's digital health transformation demonstrates that large-scale interoperable electronic health record systems can move beyond technical implementation to generate measurable population-level health system outcomes when supported by strong governance frameworks, national leadership, and integrated digital health strategies. The findings from this study provide empirical evidence that digital health investments, when strategically coordinated and aligned with national health priorities, can contribute significantly to healthcare system strengthening, continuity of care, service delivery improvement, and evidence-based decision-making within low- and middle-income country (LMIC) settings.

The implementation of SmartCare Pro as a nationally coordinated electronic health record platform enabled substantial expansion of digital health coverage across Zambia's healthcare system. With more than 12.5 million registered client records captured across all provinces, the platform has become one of the largest integrated digital health systems in sub-Saharan Africa. This achievement reflects Zambia's transition from fragmented, program-specific information systems toward an integrated national digital health ecosystem capable of supporting patient-level healthcare management and population-level health intelligence.

The study findings further demonstrate that interoperability plays a critical role in improving operational efficiency and healthcare coordination. Integration between SmartCare Pro and logistics management systems strengthened prescription-to-dispensing linkage, improved medicine stock visibility, enhanced supply chain forecasting, and reduced duplication of records. These interoperability outcomes contributed to improved continuity of care and more efficient healthcare delivery processes. The findings therefore reinforce the importance of adopting interoperable digital architectures and national data exchange standards as foundational components of digital health transformation.

The demographic and provincial analyses conducted in this study also highlight important public health and equity implications. Female utilization accounted for the majority of digital health registrations, reflecting strong engagement with maternal, reproductive, and HIV-related healthcare services. However, lower male participation indicates persistent challenges related to male health-seeking behaviour and healthcare engagement. Similarly, the concentration of digital health utilization within urban provinces such as Lusaka, Southern, and Copperbelt reflects disparities in infrastructure availability, digital readiness, and healthcare accessibility between urban and rural settings.

These findings underscore the need for future digital health investments to prioritize equitable expansion of healthcare technologies and infrastructure in underserved and rural areas. Investments in internet connectivity, electricity supply, digital equipment, workforce training, and infrastructure strengthening will be essential for reducing geographic disparities and ensuring that digital transformation contributes to equitable healthcare access across the country.

The study also confirms that governance is a fundamental determinant of successful digital health implementation. Zambia's governance-driven approach, supported through the National Digital Health Strategy, Interoperability Architecture Framework, and Health Data Governance Framework, enabled coordinated implementation, national ownership, system integration, and sustainability. The experience from Zambia

demonstrates that digital transformation is not solely a technological exercise but rather a comprehensive institutional and health systems strengthening process requiring strategic leadership, policy alignment, stakeholder coordination, and accountability mechanisms.

Importantly, the findings illustrate that digital health systems can support broader health system functions beyond routine data capture and reporting. The integrated digital health ecosystem contributed to improved clinical decision support, disease surveillance, healthcare coordination, resource allocation, and national health intelligence. The ability to utilize real-time patient-level information for planning and operational decision-making strengthens the responsiveness and resilience of the healthcare system, particularly within resource-constrained settings.

The study therefore contributes to the growing implementation science evidence demonstrating that digital health technologies can generate meaningful operational and population-level outcomes in LMIC contexts when implemented within integrated governance and interoperability frameworks. Zambia's experience provides a practical implementation model for other countries seeking to strengthen healthcare delivery through coordinated digital transformation strategies.

Future digital health priorities in Zambia should focus on strengthening interoperability maturity, expanding digital health infrastructure to rural and underserved populations, enhancing workforce digital competencies, and developing advanced analytics and artificial intelligence capabilities capable of supporting predictive health intelligence and decision-making. Additional emphasis should also be placed on sustainability planning, cybersecurity, data protection, and integration of private sector healthcare data into national digital ecosystems.

Furthermore, future research should explore the long-term effects of digital transformation on healthcare quality, patient outcomes, health financing efficiency, and disease burden reduction. Comparative studies examining digital health implementation across different LMIC settings may also provide additional insights regarding scalability, contextual adaptation, and sustainability of national digital health ecosystems.

In conclusion, Zambia's digital health transformation demonstrates that interoperable electronic health record systems, when anchored within governance-driven national strategies, can become powerful instruments for healthcare system strengthening, evidence-based planning, continuity of care, and Universal Health Coverage. The findings reinforce the position that digital health systems are not merely technical platforms, but strategic national assets capable of transforming healthcare delivery, strengthening public health intelligence, and improving population health outcomes in resource-constrained environments.

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Author Contributions

Andrew Kashoka conceptualized the study, designed the methodology, conducted data analysis, interpreted the findings, and prepared the manuscript. The author also reviewed national digital health policy documents, interoperability frameworks, governance

instruments, and implementation reports utilized in the study. The final manuscript was reviewed and approved by the author.

Conflict of Interest

The author declares no conflict of interest.

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Ethical Approval

Ethical approval was obtained from the Ministry of Health Zambia.

Data Availability

Data utilized in this study are available from the corresponding author upon reasonable request.

References

[1]. WHO, 2021, Global strategy on digital health. *World Health Organization*, Geneva.

[2]. World Bank, 2020, Digital development in Africa. *World Bank Publications*, Washington DC.

[3]. African Union, 2020, Digital transformation strategy for Africa (2020–2030). *African Union Commission*, Addis Ababa.

[4]. Labrique, A., Vasudevan, L., Kochi, E., Fabricant, R., Mehl, G., 2018, Digital health and health systems strengthening in low- and middle-income countries. *PLoS Medicine*, 15(11), e100264.

[5]. Mutale, W., Chintu, N., Amoroso, C., Awoonor-Williams, K., Phillips, J., Baynes, C., 2019, Improving health information systems for decision making across five sub-Saharan African countries. *Health Research Policy and Systems*, 17(1), 1–12.

[6]. OpenHIE, 2020, OpenHIE architecture specification framework. *OpenHIE Community*.

[7]. Ministry of Health Zambia., 2022, National Digital Health Strategy 2022–2026. *Ministry of Health*, Lusaka.

[8]. Digital Square, 2019, Interoperability standards for digital health systems. *PATH*, Seattle.

[9]. GSMA, 2020, Digital health in Africa: Opportunities and challenges. *GSMA Mobile for Development*.

[10]. UNAIDS., 2022, Digital health and HIV service delivery. *UNAIDS*, Geneva.

[11]. UNICEF., 2019, Digital health interventions for maternal and child health. *UNICEF*, New York.

[12]. Scott, R., Mars, M., 2015, Telehealth in Africa: A review of the literature. *Studies in Health Technology and Informatics*, 211, 1–8.

[13]. Braa, J., 2012, Health information systems and organizational change in developing countries. *Information Technology for Development*, 18(1), 1–8.

[14]. Hersh, W., 2020, Health informatics: Practical guide for healthcare and information technology professionals. *Lulu Press*, North Carolina.

[15]. Mehl, G., Labrique, A., 2014, Prioritizing integrated mHealth strategies for universal health coverage. *Science*, 345(6202), 1284–1287.

[16]. Ouma, S., 2021, Implementation science approaches in health systems strengthening. *African Journal of Health Systems*, 8(2), 45–59.

[17]. European Commission., 2020, Digital maturity models for healthcare transformation. *European Commission Publications*, Brussels.

[18]. Global Digital Health Index., 2022, Country digital health profiles and maturity assessment. *Global Digital Health Index*.

[19]. Jembi Health Systems., 2021, OpenHIE architecture and interoperability implementation guide. *Jembi Health Systems*, South Africa.

[20]. Shen, Y., 2023, Digital transformation and health system resilience in low-income countries. *International Journal of Medical Informatics*, 172, 104998.