

Transition from paper-based to digital systems involving Biometrics utilisation in healthcare facilities in Lusaka, Zambia

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Abstract

Background: The transition from paper-based to digital systems in healthcare facilities has been driven by the need for improved efficiency and accuracy. Implementing biometric systems, such as fingerprint recognition, has been a significant component of this digital transformation. This study aimed to assess the transition from paper-based to digital systems utilising biometrics in healthcare facilities in Lusaka, Zambia

Objective: to assess the transition from paper-based to digital systems utilising biometrics in healthcare facilities in Lusaka, Zambia

Methods: A phenomenological approach was employed to gather in-depth insights from participants, including Ministry of Health officials, healthcare workers, and end-users (patients). Semi-structured interviews were conducted across selected healthcare facilities in Lusaka Province, with data collected in both English and Chinyanja. Thematic analysis using NVivo version 12 was applied to identify recurring themes and patterns related to implementing and managing biometric systems.

Results: The study found that biometric systems significantly improved the efficiency of patient identification and data management. Participants reported enhanced accuracy in patient records, reduced duplication, and streamlined access to information. However, challenges such as technical issues related to power outages and privacy concerns were noted. Additionally, barriers to acceptance included a lack of information, logistical challenges, and community misconceptions about the technology.

Conclusions: The transition to digital systems, particularly the integration of biometric technologies, has demonstrated considerable benefits in healthcare settings, including improved data accuracy and operational efficiency. Despite these advantages, addressing the technical and perceptual challenges, along with enhancing community education, is crucial for maximizing the benefits of biometric systems and achieving a successful transition to digital healthcare in Lusaka, Zambia.

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Original Manuscript

Transition from paper-based to digital systems involving Biometrics utilisation in healthcare facilities in Lusaka, Zambia

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Abbreviations

Chinyanja	A local language in Zambia
HIV	Human Immunodeficiency Virus
IDIs	In-depth Interviews
ICT	Information Communication Technology
LAMUBREC	Lusaka Apex Medical University Biomedical Research Ethics Committee
MoH	Ministry of Health
NHIMA	National Health Insurance Management Authority
NHRA	National Health Research Authority
NVivo	A qualitative data analysis software

Abstract

Background: The transition from paper-based to digital systems in healthcare facilities has been driven by the need for improved efficiency and accuracy. Implementing biometric systems, such as fingerprint recognition, has been a significant component of this digital transformation. This study aimed to assess the transition from paper-based to digital systems utilising biometrics in healthcare facilities in Lusaka, Zambia

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Conclusion: The transition to digital systems, particularly the integration of biometric technologies, has demonstrated considerable benefits in healthcare settings, including improved data accuracy and operational efficiency. Despite these advantages, addressing the technical and perceptual challenges, along with enhancing community education, is crucial for maximizing the benefits of biometric systems and achieving a successful transition to digital healthcare in Lusaka, Zambia.

Keywords:

Biometric Systems, Digital Transition, Healthcare, Patient Identification, Zambia

Background

The transition from paper-based to digital systems in healthcare has marked a significant shift in how patient information is managed, enhancing both efficiency and accessibility (Okolo et al., 2024). Traditional paper records, although familiar, are plagued by inefficiencies, high error rates, and susceptibility to loss, leading to delays in treatment and communication breakdowns among healthcare providers (Overton, 2019). Additionally, the physical nature of these records poses challenges for information sharing across departments, further complicating patient care (Reegu et

al., 2023).

In response to these challenges, healthcare systems worldwide are increasingly adopting digital technologies such as Electronic Health Records (EHRs), Health Information Systems (HIS), and telemedicine platforms (Maraj et al., 2024). These systems facilitate the electronic storage, retrieval, and sharing of patient data, substantially improving the efficiency of healthcare delivery. The COVID-19 pandemic has underscored the need for robust digital infrastructures to support remote care and patient management, accelerating the adoption of these technologies (Shao et al., 2023)

Biometric technologies, including fingerprint scanning, facial recognition, iris scanning, and voice recognition, have emerged as crucial tools in healthcare to enhance security and streamline patient identification (Ahmed and Asghar, 2023). By ensuring accurate data linkage, these technologies reduce the risk of medical errors and fraud. Countries like Estonia (Menshikov and Volkova, 2019), and Denmark (Slawomirski and Oderkirk, 2017) have set examples by successfully implementing biometric systems, resulting in improved patient outcomes and more efficient healthcare processes.

Despite the global trend towards digitalization, healthcare systems in sub-Saharan Africa, particularly Zambia, face unique challenges in adopting digital and biometric technologies (Hamapa et al., 2024, Musoni et al., 2023). These challenges include inadequate infrastructure, insufficient training, and a lack of technical expertise. In response, Zambia's Ministry of Health has prioritized digital health innovation within its 8th National Development Plan (2022-2026), aiming to integrate digital services to improve healthcare delivery and align with global health standards (Milukutu and Siachisa, 2023, Muyunda and Mpundu, 2023, Organization, 2024). The National eHealth Strategy (2017-2021) further outlines Zambia's vision for secure and accessible health information through an integrated eHealth system, with support from international collaborations like WHO's Digital Adaptation Kits (DAKs) (Chilunjika et al., 2024, Mamuye et al., 2022, Muyunda and Mpundu, 2023, Victor et al., 2023).

However, significant gaps remain in understanding how biometric systems are specifically implemented in healthcare settings and the potential privacy implications for patients (Newaz et al., 2021). Privacy by design principles is essential to ensure that personal data is collected, stored, and shared securely and transparently (Saltarella et al., 2023, Semantha et al., 2023). Addressing privacy concerns, along with the technical challenges of internet connectivity, interoperability, and community engagement, is crucial for the successful adoption of these technologies (Karpakavalli, 2024).

In resource-limited settings like sub-Saharan Africa including Zambia, the adoption of digital and biometric systems holds the potential to revolutionize healthcare delivery by improving patient identification, reducing errors, and streamlining administrative processes (Anne et al., 2020). Nevertheless, the success of these systems hinges on overcoming the region's unique challenges, such as limited infrastructure and the need for robust training and community buy-in (George et al., 2016). The study aimed to assess the transition from paper-based to digital systems utilising biometrics in healthcare facilities in Lusaka, Zambia. This represents a crucial advancement in healthcare delivery, with the potential to improve efficiency, precision, and patient safety. Embracing these technologies will be pivotal in addressing the needs of underserved populations and improving overall health outcomes.

2 Methodology

2.1 Study design

This study employed a phenomenological approach (Williams, 2021), to assess the transition from paper-based to digital systems utilizing biometrics in healthcare facilities in Lusaka, Zambia. The study aimed to gain in-depth insights into the experiences and perceptions of Ministry of Health officials, healthcare workers, and patients regarding the implementation and management of biometric systems. Conducted in selected healthcare facilities within Lusaka Province, the research explored the challenges and benefits of shifting from traditional paper-based health records to digital formats. Additionally, it evaluated the levels of adoption and the perceived improvements in

operational efficiency as reported by key stakeholders. All research activities adhered to ethical guidelines and regulations to ensure compliance and maintain data integrity.

2.2 The research sites

The study was conducted in four healthcare facilities within the District of Lusaka, Zambia: Chilenje, Chawama, Kanyama, 1st Level Hospital and Railways Urban Clinic. These facilities were purposefully selected because they provide fingerprint biometric services under the National Health Insurance Management Authority (NHIMA). NHIMA, a public entity run by the Zambian government, oversees the implementation of national health insurance services, aiming to improve healthcare accessibility and affordability for Zambians. Biometric systems, such as fingerprint identification, are utilised under NHIMA to ensure accurate patient identification, streamline service delivery, and prevent fraudulent claims.

Each facility offers medical services, including primary care, emergency care, maternal and child health services, minor surgical procedures, and inpatient care for common illnesses. They serve diverse populations, with catchment areas ranging from 20,000 to 90,000 people. For example, Chawama 1st Level Hospital piloted an ear biometric identification tool, Railways Clinic tested a fingerprint biometric system, while Chilenje and Kanyama 1st Level Hospital integrated fingerprint biometrics as part of their NHIMA services. Biometric systems are used primarily for patient registration, tracking, and verification to ensure efficient delivery of healthcare services.

Data for the study were collected over five months, from August to December 2023, focusing on the experiences and perceptions of healthcare workers, Ministry of Health officials, and patients interacting with these systems. This approach provided insights into the operational dynamics, challenges, and perceived benefits of transitioning to digital systems in these healthcare facilities.

2.3 Sampling strategy and participants

The participants in this study were categorised into three groups: Ministry of Health (MoH) officials, healthcare workers (HCWs), and end-users (patients), as shown in Table 1. Using a purposive sampling strategy, participants were selected based on their direct involvement with the biometric systems provided by the National Health Insurance Management Authority (NHIMA), ensuring a comprehensive exploration of the transition from paper-based to digital systems. The MoH officials (n = 2) included an Information and Website Management Officer and a Principal Information Communication Technology Officer, who provided critical insights into policies and the implementation of biometric systems. The HCWs (n = 12) comprised Senior Medical Superintendents, Matrons, and Information Officers, whose diverse professional roles offered an in-depth understanding of system functionality and challenges. The end-users (n = 16) included nine outpatient primary healthcare users (three males and six females) and seven mothers who attended the Mother and Child Health (MCH) Unit for maternal healthcare services, offering valuable feedback on accessibility and user experience with biometric systems. Participants were excluded if they did not access services for primary or maternal healthcare, did not utilise biometric systems, or were unwilling to participate in face-to-face interviews. Recruitment involved accessing MoH officials through their offices, HCWs via Matrons and OPD in-charges, and end-users at the OPD and MCH Unit, ensuring a sample size sufficient for data saturation (Saunders et al., 2018).

Table 1 Summary of the demographics of the participants

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Designation	Gender	Number
Senior medical superintendent facility in-charge	Females and a male	4
Matrons	Females	4

Designation	Gender	Number
Information officer	Males	4
End-user (patients) from OPD	Patients	16
Ministry of Health officers	Males	2
Total		30

Distribution of study participants who used fingerprint and ear biometrics

2.4 Trustworthiness

To ensure the study's trustworthiness, several strategies were utilized. Credibility was strengthened by engaging with participants for extended periods and having them review and confirm the accuracy of transcriptions and interpretations. Transferability was addressed by providing detailed descriptions of the research context, participants, and procedures, allowing readers to assess the applicability of the findings to other contexts. Dependability was maintained by documenting all research decisions and changes made during the study. Confirmability was achieved through reflexivity, with the researchers continuously reflecting on their biases and how they might have influenced the research process and findings (Kelp and Simion, 2023).

2.5 Data collection methods and tools

The research study employed face-to-face semi-structured interviews (Barriball and While, 1994) with end-users (patients), Ministry of Health officials, and healthcare workers to gather in-depth information. This approach involved using open-ended questions (Husain et al., 2012, Züll, 2016) to explore participants' perspectives on the implementation and impact of biometric systems in healthcare facilities within Lusaka Province. An interview guide with open-ended questions facilitated a two-way conversation, allowing for a thorough exploration of relevant themes. The in-depth interviews included patients who utilized fingerprint biometrics, accessed either through the Maternal Child Health Unit or the Outpatient Department. Across all interviews, the use of open-ended questions enabled a deeper understanding of the participants' experiences and views.

The principal investigator, and trained research assistants, conducted individual in-depth interviews (IDIs) to explore the transition from paper-based to digital systems involving biometric utilisation in healthcare facilities. Interviews with end-users (patients), Ministry of Health officials and healthcare workers were conducted in English and the local language, Chinyanja, depending on participants' preferences. The principal investigator and two trained research assistants provided language assistance during these interviews. This bilingual approach was designed to capture nuanced insights from Ministry of Health officials, healthcare workers, and end-users (patients) while considering linguistic and cultural factors in the research process.

Audio recorders were used to conduct face-to-face interviews, each lasting 35 to 65 minutes. The recorded interviews were transcribed verbatim, coded using NVivo version 12, and analysed through an inductive thematic analysis approach.

2.6 Data collection procedure

Before conducting the interviews, participants were briefed on the study's objectives, and informed consent was obtained. They were made aware that participation was entirely voluntary, with no financial incentives provided. To ensure confidentiality, pseudonyms were used to protect participants' identities. Importantly, there was no prior relationship between the participants and the research assistants, which helped minimise potential biases and influence on participants' responses. The research assistants approached the participants as independent researchers, fostering an environment where Ministry of Health officials, healthcare workers, and end-users (patients) could

freely share their honest and unfiltered perspectives on the implementation and impact of biometric systems in healthcare facilities. Data were securely stored on a password-protected computer, with access restricted to the principal investigator. Both verbal and written consent were obtained from all participants, and their demographic details were collected using standardised forms.

2.7 Data management and analysis

The study employed a thematic analysis approach as the foundation for its data analysis process. Thematic analysis systematically identifies recurring themes, patterns, and insights from the collected data (Riger and Sigurvinsdottir, 2016). The data gathered through interviews and focus group discussions, were carefully transcribed and organised. Following transcription, the data were coded, classified, and grouped into themes reflecting the perspectives, concerns, and experiences of healthcare workers and patients. NVivo version 12 software was utilised to facilitate this process. The resulting themes encompassed a variety of factors influencing the utilisation and adoption of biometric systems, including technical considerations, economic aspects, regulatory compliance, ethical concerns, and operational challenges.

2.8 Ethical considerations

The study received ethical approval from the Lusaka Apex Medical University Biomedical Research Ethics Committee (LAMUBREC) (Ref No: 00513–22) and the National Health Research Authority (NHRA) (Ref No: NHRA000007/23/02/2023) prior to the commencement of data collection. Additionally, permission to conduct the research was obtained from the provincial health office, allowing access to the necessary facilities. Gatekeepers at the Ministry of Health and each selected healthcare facilities granted further permission to carry out the research within their premises. Eligible participants were approached and provided with informed consent documents in both English and Chinyanja. Informed consent was obtained from all participants in both verbal and written forms. To maintain anonymity, participants were assigned pseudonyms and were explicitly informed that their participation was voluntary, with the option to withdraw at any time without repercussions. Throughout the study, stringent confidentiality measures were implemented to safeguard participant privacy and sensitive information.

2.9 Findings

As shown in Table 2, we involved two Ministry of Health Officials, four healthcare facility in-charges, four information officers, and four Matrons. All of these study participants had work experience ranging from six months to two years at the time of the research. Additionally, there were sixteen end-users (patients) included in the study. These individuals were actively serving in the outpatient department, which is the primary entry point for all patients at the healthcare facility. It's important to note that this department had implemented a fingerprint biometric system as part of its operational framework.

Table 2 Demographic characteristics of participants

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Position	Chilenje	Railways	Kanyama	Chawama	Totals
Senior medical superintendent	1		1	1	3
Facility in-charge		1			1

Position	Chilenje	Railways	Kanyama	Chawama	Totals
Matron	1	1	1	1	4
Information officers	1	1	1	1	4
Ministry of Health officials					2

The study explored the transition from Paper-based to Digital Systems Involving Biometrics Utilisation in Healthcare Facilities, focusing on several key themes: the transition from paper-based to digital systems, biometric integration and utilisation, perceived advantages, challenges and disadvantages, and barriers to acceptance.

The table below categorizes the various findings into structured themes and codes, helping to clearly present the information.

Table 3, Major Themes, Emergent Themes, and Codes:

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Major Themes	Emergent Themes	Codes
Transition from paper-based to digital systems	Initial motivation and challenges	Inefficiencies of paper-based systems, time-consuming, logistical issues, need for efficiency
	Planning and implementation	Needs assessment, strategic documents, committees, resource mobilization
	Technological integration	Fingerprint biometrics, record management, processing time, workflow improvement
Biometric integration and utilization	Ease of use and impact on workflow	User-friendly, quicker service, no need for physical files, improved record management
	Accuracy and data retrieval	Patient record accuracy, fingerprint retrieval, continuity of care, error reduction
Perceived advantages	Improvement in patient identification and data quality	Unique identifier, data quality improvement, reduced duplication

	Reduction in duplicate records and enhanced efficiency	Efficiency, elimination of temporary cards, simplified healthcare operations
Challenges and disadvantages	Technical issues and dependence on infrastructure	Power outages, system downtime, prolonged wait times, patient frustration
	Privacy concerns and perceptual beliefs	Disease exposure fears, foreign concept perceptions, resistance due to cultural beliefs
Barriers to acceptance	Lack of information and education	Need for health education, community sensitization, resistance due to misunderstanding
	Logistical challenges in implementation	Inconsistent electricity, System downtime
	community perception and misconceptions	Foreign concept association, "satanism" misconceptions, barriers to acceptance

1. Experiences and perceptions of the transition to biometric systems in healthcare

This chapter presents the findings from interviews with Ministry healthcare professionals and patients regarding their experiences and perceptions of the transition from paper-based to digital biometric systems within healthcare facilities. The findings are organized into thematic sections, including experiences with the transition, perceived advantages and challenges, and barriers to acceptance.

2. Transition from paper-based to digital systems

Initial motivation and challenges

The transition from paper-based to digital systems was motivated by the inefficiencies associated with the older system, particularly within healthcare facilities. Participants reported that between 2011 and 2013, the realization that the paper-based system was time-consuming and fraught with logistical challenges such as appointment delays drove the move to digital systems. The need for a more efficient and streamlined approach to managing patient information was a key factor in this decision as explained below:

The old system was time-consuming. Patients often faced appointment delays, and there were significant logistical issues...(IDI/MoH/ Information and Website Management Officer)

We wanted to improve turnaround times and gain efficiency...(IDI/MoH/principal ICT officer)

The integration of digital health systems like Smart Care became a crucial part of this transformation, leading to more streamlined operations.

Planning and implementation

The transition was meticulously planned, with participants indicating the comprehensive needs assessments and development of strategic documents like the Digital Health Strategy (2022-2026) by stakeholders, including Ministry of Health officials, hospital administrations, and external partners, played vital roles in planning and resource mobilization. Committees were established to oversee

various aspects of the transition, ensuring that the shift was well-coordinated and aligned with broader health system goals as stated below:

We conducted a comprehensive needs assessment and formed committees to oversee the transition....(IDI/MoH/Principal ICT officer)

The strategy documents were essential. They provided a roadmap for how we could achieve our digital health goals....(IDI/SMS/Chilenje 1st Level Hospital)

3. Biometric integration and utilisation

Technological integration

Biometric technologies, particularly fingerprint biometrics, were identified as pivotal in enhancing the efficiency of patient registration and record management. Information Officer from Chilenje 1st Level Hospital highlighted that these technologies have simplified patient record management, reduced processing times, and improved overall workflow. As shown below, an Information and Website Management Officer indicated that a biometrics system has been installed and that there are future considerations to expand biometrics to include iris recognition, reflecting ongoing technological advancements in the healthcare sector.

Currently, we have installed fingerprint biometrics, and the iris one is something that we're looking into so that we can incorporate both the thumbprint and the eye facial...(IDI/MoH/Information and Website Management Officer)

Ease of use and impact on workflow:

The implementation of biometric tools in healthcare settings has been met with overwhelmingly positive feedback from both patients and healthcare providers. Participants highlighted the ease of use of these systems, emphasising how they have significantly enhanced the efficiency of medical services. Described as quicker and more efficient, biometric tools have streamlined the process of patient management, allowing healthcare providers to serve patients more rapidly while managing records with greater ease. One clinical officer expressed,

Since the system has been in use, patients have accepted it well... they no longer need to bring a file or card; they can walk in and, after using the biometric system, all their information can be accessed securely...(IDI/Clinical Officer/Railways Urban Clinic).

Similarly, a matron from Chawama 1st Level Hospital praised the user-friendliness of the system, noting,

The biometric system is very straightforward and user-friendly. It's made the process much faster, allowing us to attend to more patients in less time and manage records more efficiently (IDI/Matron/Chawama 1st Level Hospital)

The commendations highlight the significant impact of biometric systems on healthcare delivery. They have improved the speed and efficiency of services and enhanced the overall patient experience by eliminating the need for physical files or cards.

Accuracy and data retrieval:

The introduction of biometric systems in healthcare has notably enhanced the accuracy and reliability of patient records, as well as restructured the retrieval of information. This advancement has proven particularly beneficial in cases where patients lose their hospital cards. With biometrics, healthcare providers can still access patient information using fingerprints, thus minimizing record duplication and ensuring uninterrupted care. As one Senior Medical Superintendent remarked,

Even if clients lose their card, with biometrics, we can still find the information for the client... (IDI/SMS/Chilenje 1st Level Hospital).

This capability ensures that patients' medical histories are readily accessible, which is crucial for maintaining continuous care without disruptions. Additionally, a Principal ICT Officer from the Ministry of Health highlighted the impact on error reduction and care continuity, stating,

Even if a patient loses their hospital card, we can still access their complete medical history using their fingerprints. This has drastically reduced errors and ensured that care is continuous without any interruptions due to lost records...(IDI/MoH/Principal ICT officer).

4. Perceived advantages

Improvement in patient identification and data quality

Participants highlighted the significant improvement in patient identification and data quality with the introduction of biometric systems. Each patient is now assigned a unique identifier, which has enhanced the accuracy and reliability of patient records. The Information Officer at Chawama 1st Level Hospital noted,

We will avoid duplication of information... it has also improved our data quality for retention, especially for patients with HIV...(IDI/Information Officer/Chawama 1st Level Hospital).

Reduction in duplicate records and enhanced efficiency:

The biometric system's ability to eliminate duplicate records was seen as a major advantage. Participants noted that the system has improved the efficiency of accessing patient information, as it no longer requires temporary cards, which were common in the paper-based system, commented the Senior Medical Superintendent.

The fingerprint system used by NHIMA has simplified the lives of healthcare workers and patients...(IDI/SMS/Chilenje 1st Level Hospital).

5. Challenges and disadvantages

Technical issues and dependence on infrastructure

The shift to digital systems, including biometrics, has brought about various challenges, especially for patients who face significant disruptions caused by power outages. Participants emphasized the reliance on a stable electricity supply, which is not always dependable in the region. Regular power outages results in the entire system going offline, leading to operational disruptions and prolonged wait times for patients. One end-user (patient) expressed frustration with the situation, while another end-user (patient) from Railways Urban Clinic shared their concerns, highlighting the difficulties caused by frequent power cuts for the digital system. See quotes below:

Whenever there's a power outage, the system goes down, and we end up waiting for hours before we can be attended to. It's frustrating because the wait times can be long... (IDI/Patient/Chilenje 1st Level Hospital).

The frequent power cuts make it difficult to rely on digital systems. Sometimes we have to come back another day because the system is down and our records can't be accessed... (IDI/Patient/Railways Urban Clinic).

Privacy concerns

Privacy concerns were also noted, with some patients fearing that the biometric system could expose them to diseases. One participant expressed this concern, highlighting the worry that patients using biometric systems might be exposed to diseases due to shared equipment. According to study participants, these fears stemmed from the perception that the repeated use of biometric devices, such as fingerprint scanners, by multiple patients could facilitate the transmission of infections.

Some patients are worried that using the biometric system might expose them to diseases because of shared equipment....(IDI/Patient Railways Urban Clinic)

Perceptual beliefs

Several participants expressed concerns about the system being perceived as a foreign concept imposed by outsiders, which negatively impacted its acceptance among certain segments of the patient population. One participant highlighted this sentiment:

We were never involved in the decision-making; it just came from above, so people don't trust it...(IDI/Patient/Chawama 1st Level Hospital)

Patients feel that it's a foreign idea imposed on us and are not comfortable with it...(IDI/information officer/Chilenje 1st level hospital)

6. Barriers to acceptance

Lack of information and education

Participants highlighted the need for comprehensive health education and community sensitization to foster acceptance of biometric systems. They indicated that a lack of information and understanding about how these systems work has contributed to resistance among some end-users (patients).

There is a strong need for more information and education about how these biometric systems work. Many patients resist because they simply don't understand the technology or its benefits. More outreach could help in overcoming these barriers...(IDI/Patient/Chawama 1st Level Hospital).

Logistical challenges in implementation

In addition to educational barriers, a Matron from Chawama 1st level Hospital highlighted logistical challenges, particularly inconsistent electricity supply, which were identified as significant obstacles to the successful implementation of biometric systems. See quote below:

Our setup sometimes has no electricity, and the whole system is down... (IDI/Matron/Chawama 1st Level Hospital).

Community perception and misconceptions

Misconceptions about biometric tools were also highlighted, with some end-users (patients) associating these technologies with foreign concepts or even "Satanism." These perceptions have created additional barriers to acceptance, underscoring the need for ongoing community engagement and education to address and dispel these misconceptions.

Some patients view the biometric system as something foreign or even associate it with negative ideas like 'Satanism.' These misconceptions create additional barriers to acceptance and highlight the urgent need for ongoing community engagement and education" (IDI/Patient/Chawama 1st Level Hospital).

3 Discussion

The study delves into the complex transition from traditional paper-based record-keeping systems to advanced digital biometric systems in healthcare, focusing on the experiences of key participants, including Ministry of Health officials, healthcare workers, and end-users (patients). Utilizing a thematic approach (Ham and Weiler, 2004), the findings underscore the experiences and perceptions of this transition, covering key aspects such as biometric integration and utilization, perceived advantages and challenges, and broader implications of the shift. The discussion highlights critical themes, including system integration, data accuracy and security, user adaptability, and the impact on healthcare delivery efficiency. Additionally, it explores how participants' perceptions of the technology influence the successful implementation and sustainability of biometric systems within the healthcare sector.

3.1 Experiences and perceptions of the transition to Biometric systems in healthcare

The transition from traditional paper-based systems to digital biometric systems has been generally well-received, with participants highlighting significant improvements in patient identification, data quality, and efficiency in healthcare delivery. This positive reception is consistent with the findings from the study "Biometrics Technology: Attitudes & Influencing Factors When Trying to Adopt This Technology in Blekinge Healthcare" by (Iqbal and Qadir, 2012), which also highlights similar benefits in other regions, particularly in sub-Saharan Africa, where biometric systems have improved service delivery and reduced administrative burdens.

Additionally, a study titled "Are We Getting the Biometric Bioethics Right? The Use of Biometrics within the Healthcare System in Malawi" (Mwapasa et al., 2020), found that the transition to digital biometric systems was well-received, with participants noting increased operational efficiency and improved patient data management. This study highlights the practical advantages of implementing biometric technologies in healthcare, indicating that the shift from paper-based processes effectively addresses existing inefficiencies.

3.2 Transition from paper-based to digital systems

The findings on the shift to digital systems in healthcare were primarily motivated by the need to address inefficiencies inherent in paper-based methods. Participants reported that biometric tools have streamlined patient record management, reduced processing times, and improved workflow, which is consistent with broader healthcare digitisation goals aimed at enhancing service delivery and patient care. These findings align with several studies that emphasise the benefits of digital tools in improving efficiency, data management, and overall workflow in healthcare settings.

A study on "Digital Transformation in Healthcare: Technology Acceptance and Its Applications" (Stoumpos et al., 2023), highlights the potential of digital solutions to enhance healthcare quality. The study discusses how stakeholders apply and manage digital technologies for business purposes, indicating that digital transformation can lead to improved service delivery and patient care, aligning with the reported benefits of biometric tools in managing patient records and reducing processing times.

Furthermore, a study on "Factors Affecting the Transition from Paper to Digital Data Collection for Health Outreach" (Mergenthaler et al., 2022), suggests that transitioning to digital data collection enhances program efficiency and data quality by reducing time spent on data entry and management. This finding aligns with the reported improvements in workflow and data management in healthcare settings.

Another study "Paper to Digital: IT Automation and Digital Transformation on the Efficiency and Effectiveness of Clinical Trials" (Kumari, 2015), highlights the digitization of clinical trials, noting that electronic documents significantly increase efficiency and accuracy. The study emphasizes that digital solutions streamline processes and enhance data integrity, which supports the findings regarding the benefits of transitioning to digital systems in healthcare for better patient record

management and service delivery.

These studies collectively reinforce the notion that the transition from paper-based to digital systems in healthcare not only addresses inefficiencies but also enhances overall operational effectiveness, aligning well with the findings of improved patient record management and reduced processing times.

3.3 Biometric integration and utilization

Biometric technologies, particularly fingerprint recognition, have simplified the patient registration process by minimizing the reliance on physical documents and reducing the risk of record duplication. This advancement is crucial for maintaining continuous care, especially when patients lose their hospital cards. The integration of these technologies has been noted to improve overall healthcare efficiency. These findings align with the “Biometric Registration Pilot Project in Mozambique” on (Cambaco et al., 2021). This study assessed a biometric registration prototype implemented in the Manhica district of Mozambique. It found that biometric registration significantly improved the identification of children at healthcare facilities, minimizing reliance on physical documents and reducing the risk of record duplication. The registration enhanced healthcare access for children, aligning with the findings that biometric tools streamline patient registration and maintain continuity of care, especially when physical identification documents are lost.

Another study on “Clinical Study of Using Biometrics to Identify Patient and Procedure” (Sohn et al., 2020). The study highlighted that fingerprints are not subject to loss or damage like wristbands, thus preventing multiple records for one patient. The system's design aimed to improve patient identification accuracy and efficiency, supporting the claim that biometric technologies enhance overall healthcare workflow and reduce administrative errors. These studies collectively reinforce the assertion that biometric technologies, especially fingerprint recognition, play a vital role in simplifying patient registration, enhancing data accuracy, and improving overall healthcare efficiency.

3.4 Perceived advantages, challenges, and disadvantages

While the advantages of biometric systems are evident, challenges such as technical issues, privacy concerns, and community misconceptions were also identified. Technical challenges, including power outages, have been frequently reported in other contexts, emphasizing the need for robust infrastructure to support biometric systems. Privacy concerns regarding data security are particularly critical, as biometric data cannot be changed like passwords if compromised, necessitating stringent protective measures. These findings align with “Emerging Biometric Modalities and Integration Challenges” (Tiwari et al., 2024), it highlights technical issues such as algorithmic advancements, sensor fusion, and interoperability challenges. Moreover, it addresses privacy and security concerns, stressing the importance of protecting biometric data and ensuring system resilience against potential vulnerabilities, which aligns with the identified challenges in your findings.

Another study “Modern Biometric Technologies: Technical Issues and Research Opportunities” (Walia, 2015). This paper outlines various technical challenges faced by biometric systems, including issues related to the quality of biometric scanners and the statistical nature of biometric data. It also discusses the implications of these challenges for system performance and user acceptance. The study underscores that privacy concerns are critical, as biometric data cannot be changed like passwords, necessitating stringent protective measures to ensure user trust and system integrity. These studies collectively reinforce the understanding that while biometric systems offer significant advantages, they also present notable challenges that must be addressed to ensure successful implementation and acceptance.

3.5 Barriers to acceptance

Barriers to the acceptance of biometric systems often stem from community resistance, primarily driven by misconceptions about the technology. Effective community engagement and education are essential to alleviate fears and enhance understanding of the benefits of biometric technologies. Participants in various studies have suggested that increasing awareness about the usefulness of

biometric registration could significantly improve acceptance rates among healthcare providers and patients alike. Several studies reinforce these findings, emphasizing that community resistance is a significant barrier to acceptance, largely due to misconceptions about biometric systems.

For instance, a study titled "Acceptance of Biometric Systems for User Authentication and Identification" (Dobaibi, 2023), highlights that demographic factors, such as education level and age, play a significant role in the acceptance of biometric technologies. Specifically, the research found that younger and more educated individuals tend to show greater interest in and acceptance of these technologies. This suggests that community engagement and education initiatives could be particularly effective in improving the understanding and acceptance of biometric systems among various user groups.

Additionally, in "Emerging Biometric Modalities and Integration Challenges" (Tiwari et al., 2024), the integration challenges of biometric systems highlight the necessity of user-centric approaches and effective communication strategies to alleviate fears and enhance understanding of biometric benefits. It indicates that increasing awareness about biometric systems can lead to higher acceptance rates, particularly in communities where skepticism prevails.

Furthermore, in a study "Biometric Recognition: Challenges and Opportunities" (Pato et al., 2010), the findings comprehensive overview of biometric systems underscore the importance of addressing privacy concerns and ensuring that communities are adequately informed about the benefits and functionalities of these technologies. The study indicates the effective education and engagement strategies to foster acceptance and trust in biometric systems. These studies emphasize the importance of educating and engaging communities to reduce resistance to biometric systems in healthcare, leading to improved acceptance among providers and patients.

3.6 Implications and importance of findings

The successful implementation of biometric systems in healthcare has broader implications for the digitization of health services in sub-Saharan Africa (Abdulkareem and Gordon, 2023). The findings of this study highlight the potential of biometric technologies to revolutionize healthcare delivery by improving patient care and streamlining administrative processes. The findings underscore the significant potential of biometric technologies to improve healthcare delivery, enhance patient care, and streamline administrative processes. By addressing critical challenges such as infrastructure limitations, privacy concerns, and cultural barriers, these technologies can contribute to more efficient and effective healthcare systems in sub-Saharan Africa. The study emphasizes the need for ongoing efforts to optimize and sustain the benefits of biometric systems in healthcare. However, the challenges identified highlight the need for continuous investment in infrastructure, education, and community engagement to ensure the sustainability and broad acceptance of these systems.

Future research should focus on several key areas identified in this study. First, it is important to investigate the impact of infrastructure challenges, such as power outages, on the effectiveness of biometric systems in healthcare and explore potential solutions to mitigate these issues. Second, in-depth studies on privacy concerns related to biometric systems, particularly patients' perceptions of data security and associated risks, are needed to develop effective strategies for addressing these concerns. Third, research should explore the role of community engagement and education in improving the acceptance and understanding of biometric technologies, especially in regions with strong cultural or perceptual barriers. Finally, assessing the long-term impact of biometric systems on healthcare delivery, patient outcomes, and health system efficiency, with a focus on both the benefits and challenges, will provide valuable insights into the sustainability and effectiveness of these technologies.

4 Conclusion

This study sheds light on the intricate transition from traditional paper-based record-keeping systems to advanced biometric systems in healthcare settings within sub-Saharan Africa. The findings reveal that while the shift to biometric systems is largely perceived positively improving patient identification, data quality, and overall healthcare efficiency several challenges still hinder their full

potential. These challenges include technical issues, privacy concerns, and cultural barriers that can impact user acceptance and system sustainability.

The transition has notably streamlined patient registration and record management, reducing administrative burdens and enhancing the quality of healthcare delivery. This aligns with global trends in healthcare digitization, as evidenced by various studies that highlight the benefits of digital tools in improving workflow and data management. However, the success of these systems is highly contingent on robust infrastructure, effective privacy safeguards, and proactive community engagement.

The study underscores the importance of addressing these challenges through continuous investment in infrastructure, particularly in regions prone to power outages, which can disrupt biometric system operations. Additionally, the study highlights the critical need for addressing privacy concerns through stringent data security measures, as biometric data, unlike traditional passwords, cannot be easily changed if compromised.

Moreover, community engagement and education are pivotal in overcoming cultural resistance and misconceptions about biometric technologies. The findings suggest that targeted awareness campaigns and education initiatives can significantly enhance the acceptance of biometric systems, especially in communities where skepticism and resistance are prevalent.

The implications of this study are far-reaching, suggesting that biometric systems, if implemented effectively, have the potential to revolutionize healthcare delivery in sub-Saharan Africa. However, to fully realize these benefits, a holistic approach that addresses technical, social, and infrastructural challenges is essential.

5 Strengths and limitations

While the study provides valuable insights into the experiences and perceptions of transitioning to biometric systems, it is important to acknowledge its limitations. The findings are based on interviews with Ministry of Health officials, healthcare workers, and end-users (patients) from a limited number of facilities, which may not fully capture the diversity of experiences across different regions. Additionally, the study relied on self-reported data, which is subject to biases such as recall bias and social desirability bias.

The research was conducted in selected healthcare facilities within Lusaka Province, potentially limiting the broader applicability of the results. The sample size and selection process may not represent the diverse healthcare settings across Zambia, and language barriers could have influenced the accuracy of data collected, despite using both English and Chinyanja. Technological constraints, including frequent power outages, and cultural perceptions of biometric systems may have affected the adoption and efficiency of these systems. Furthermore, the study's focus on specific facilities and inherent researcher biases further constrain the extent to which the findings can be generalized to other contexts or populations.

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Author's contribution AMH designed the study, supervised data collection, authored the manuscript, and oversaw the analysis and reporting of the findings. JMZ, LH, and OK contributed to the manuscript preparation by providing evaluations and feedback. After thoroughly reviewing the final version of the paper, JMZ and LH approved it for submission.

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Data availability the datasets created and/or analysed in this study can be obtained from the corresponding author upon request.

Declarations

Ethics approval and consent to participate in the study received ethical clearance from both the Lusaka Apex Medical University Biomedical Research Ethics Committee (LAMUBREC) and the National Health Research Authority (NHRA) in Zambia. Confidentiality and anonymity of the participants were strictly maintained throughout the research. Before conducting the face-to-face interviews, participants were provided with a consent form and an information sheet to ensure they were fully informed about the study.

Consent for publication not applicable

Competing Interests The authors declare that they have no competing interests.

References

- ABDULKAREEM, A. M. & GORDON, A. 2023. Evaluating the Usability and User Acceptance of Biometric Authentication in Different Applications. *Quarterly Journal of Emerging Technologies and Innovations*, 8, 1-10.
- AHMED, I. & ASGHAR, A. 2023. Evaluating the Efficacy of Biometric Authentication Techniques in Healthcare. *International Journal of Responsible Artificial Intelligence*, 13, 1-12.
- ANNE, N., DUNBAR, M. D., ABUNA, F., SIMPSON, P., MACHARIA, P., BETZ, B., CHERUTICH, P., BUKUSI, D. & CAREY, F. 2020. Feasibility and acceptability of an iris biometric system for unique patient identification in routine HIV services in Kenya. *International journal of medical informatics*, 133, 104006.
- BARRIBALL, K. L. & WHILE, A. 1994. Collecting data using a semi-structured interview: a discussion paper. *Journal of Advanced Nursing-Institutional Subscription*, 19, 328-335.
- CAMBACO, O., GACHUHI, N., DISTLER, R., CUINHANE, C., PARKER, E., MUCAVELE, E., BASSAT, Q., CHAÚQUE, C., SAUTE, F., MUNGUAMBE, K. & SACOOR, C. 2021. Acceptability and perceived facilitators and barriers to the usability of biometric registration among infants and children in Manhiça district, Mozambique: A qualitative study. *PLoS One*, 16, e0260631.
- CHILUNJIKA, A., CHILUNJIKA, S. R. & UWIZEYIMANA, D. 2024. Implementing e-Health initiatives in Zimbabwe's public health sector. *Journal of Economic Development, Environment and People*, 13, 55-66.
- DOBAIBI, M. 2023. Acceptance of Biometric Systems for User Authentication and Identification.
- GEORGE, A. S., SCOTT, K., MEHRA, V. & SRIRAM, V. 2016. Synergies, strengths and challenges: findings on community capability from a systematic health systems research literature review. *BMC health services research*, 16, 47-59.
- HAM, S. H. & WEILER, B. 2004. Diffusion and adoption of thematic interpretation at an interpretive historic site. *Annals of leisure research*, 7, 1-18.
- HAMAPA, A. M., ZULU, J. M., KHONDOWE, O. & HANGULU, L. 2024. Healthcare workers' perceptions and user experiences of biometric technology in the selected healthcare facilities

- in Zambia. *Discover Public Health*, 21, 47.
- HUSAIN, H., BAIS, B., HUSSAIN, A. & SAMAD, S. A. 2012. How to construct open ended questions. *Procedia-Social and Behavioral Sciences*, 60, 456-462.
- IQBAL, I. & QADIR, B. 2012. *Biometrics Technology: Attitudes & influencing factors when trying to adopt this technology in Blekinge healthcare*.
- KARPAKAVALLI, M. 2024. Systems Management. *Improving Healthcare Quality and Patient Engagement: Management and Technology Insights: Management and Technology Insights*, 1.
- KELP, C. & SIMION, M. 2023. What is trustworthiness? *Noûs*, 57, 667-683.
- KUMARI, S. 2015. Paper to Digital: IT Automation and Digital Transformation on the Efficiency and Effectiveness of Clinical Trials. *International Journal of Enhanced Research in Medicines & Dental Care (IJERMDC)*, Vol. 2
- MAMUYE, A. L., YILMA, T. M., ABDULWAHAB, A., BROOMHEAD, S., ZONDO, P., KYENG, M., MAEDA, J., ABDULAZIZ, M., WUHI, T. & TILAHUN, B. C. 2022. Health information exchange policy and standards for digital health systems in africa: a systematic review. *PLOS Digital Health*, 1, e0000118.
- MARAJ, M. A. A., HOSSAIN, M. A., ISLAM, S. & ARIF, N. U. M. 2024. INFORMATION SYSTEMS IN HEALTH MANAGEMENT: INNOVATIONS AND CHALLENGES IN THE DIGITAL ERA. *International Journal of Health and Medical*, 1, 14-25.
- MENSHIKOV, V. & VOLKOVA, O. 2019. DIGITALIZATION FOR INCREASED ACCESS SECURITY TO HEALTHCARE SERVICES IN LATVIA. *Journal of Security & Sustainability Issues*, 9.
- MERGENTHALER, C., MATHEWSON, J. D., LATIF, A., TAHIR, H., MEURRENS, V., VAN WERLE, A., RASHID, A., TARIQ, M., AHMED, T., NAUREEN, F. & ROOD, E. 2022. Factors Affecting the Transition from Paper to Digital Data Collection for Mobile Tuberculosis Active Case Finding in Low Internet Access Settings in Pakistan. *Trop Med Infect Dis*, 7.
- MILUKUTU, A. & SIACHISA, M. 2023. Assessing the Impact of Digital Transformation on Employee Performance in the Public Sector: A Case Study of Zambia's Ministry of Health Headquarters (2017-2022). *International Journal of Humanities, Social Sciences and Education*.
- MUSONI, M., DOMINGO, E. & OGAH, E. 2023. Digital ID systems in Africa: Challenges, risks and opportunities.
- MUYUNDA, L. & MPUNDU, M. 2023. Mapping the Regulatory Framework for Telemedicine in Zambia: A Content Analysis. *International Journal*, 10, 3445-3461.
- MWAPASA, M., GOODING, K., KUMWENDA, M., NLIWASA, M., KASWASWA, K., SAMBAKUNSI, R., PARKER, M., BULL, S. & DESMOND, N. 2020. "Are we getting the biometric bioethics right?"—the use of biometrics within the healthcare system in Malawi. *Global Bioethics*, 31, 67-80.
- NEWAZ, A. I., SIKDER, A. K., RAHMAN, M. A. & ULUAGAC, A. S. 2021. A survey on security and privacy issues in modern healthcare systems: Attacks and defenses. *ACM Transactions on Computing for Healthcare*, 2, 1-44.
- OKOLO, C. A., IJEH, S., AROWOOGUN, J. O., ADENIYI, A. O. & OMOTAYO, O. 2024. Reviewing the impact of health information technology on healthcare management efficiency. *International Medical Science Research Journal*, 4, 420-440.
- ORGANIZATION, W. H. 2024. Independent review of the Working for Health programme and its Multi-Partner Trust Fund: 2017–2022. Opportunities for future programming.
- OVERTON, B. C. 2019. *Unintended consequences of electronic medical records: An emergency room ethnography*, Rowman & Littlefield.
- PATO, J. N., MILLETT, L. I., COUNCIL, N. R. & COMMITTEE, W. B. 2010. Cultural, social, and

- legal considerations. *Biometric Recognition: Challenges and Opportunities*. National Academies Press (US).
- REEGU, F. A., ABAS, H., GULZAR, Y., XIN, Q., ALWAN, A. A., JABBARI, A., SONKAMBLE, R. G. & DZIYAUDDIN, R. A. 2023. Blockchain-based framework for interoperable electronic health records for an improved healthcare system. *Sustainability*, 15, 6337.
- RIGER, S. & SIGURVINSDOTTIR, R. 2016. Thematic analysis. *Handbook of methodological approaches to community-based research: Qualitative, quantitative, and mixed methods*, 33-41.
- SALTARELLA, M., DESOLDA, G., LANZILOTTI, R. & BARLETTA, V. S. 2023. Translating Privacy Design Principles Into Human-Centered Software Lifecycle: A Literature Review. *International Journal of Human-Computer Interaction*, 1-19.
- SAUNDERS, B., SIM, J., KINGSTONE, T., BAKER, S., WATERFIELD, J., BARTLAM, B., BURROUGHS, H. & JINKS, C. 2018. Saturation in qualitative research: exploring its conceptualization and operationalization. *Quality & quantity*, 52, 1893-1907.
- SEMANTHA, F. H., AZAM, S., SHANMUGAM, B. & YEO, K. C. 2023. PbDinEHR: A novel privacy by design developed framework using distributed data storage and sharing for secure and scalable electronic health records management. *Journal of Sensor and Actuator Networks*, 12, 36.
- SHAO, D., MWANGAKALA, H., ISHENGOMA, F., MONGI, H., MAMBILE, C. & CHALI, F. 2023. Sustenance of the digital transformations induced by the COVID-19 pandemic response: Lessons from Tanzanian public sector. *Global Knowledge, Memory and Communication*, 72, 700-713.
- SLAWOMIRSKI, L. & ODERKIRK, J. 2017. Digital technology: Making better use of health data. *New Health Technologies: Managing Access, Value and Sustainability*, 185.
- SOHN, J. W., KIM, H., PARK, S. B., LEE, S., MONROE, J. I., MALONE, T. B., KINSELLA, T., YAO, M., KUNOS, C., LO, S. S., SHENK, R. & MACHTAY, M. 2020. Clinical Study of Using Biometrics to Identify Patient and Procedure. *Front Oncol*, 10, 586232.
- STOUMPOS, A. I., KITSIOS, F. & TALIAS, M. A. 2023. Digital Transformation in Healthcare: Technology Acceptance and Its Applications. *Int J Environ Res Public Health*, 20.
- TIWARI, S., RAJA, R., WADAWADAGI, R. S., NAITHANI, K., RAJA, H. & INGLE, D. 2024. Emerging Biometric Modalities and Integration Challenges. *Online Identity-An Essential Guide*. IntechOpen.
- VICTOR, A. A., FRANK, L. J., MAKUBALO, L. E., KALU, A. A. & IMPOUMA, B. 2023. Digital Health in the African Region Should be Integral to the Health System's Strengthening. *Mayo Clinic Proceedings: Digital Health*, 1, 425-434.
- WALIA, M. S. 2015. Modern Biometric Technologies: Technical Issues and Research Opportunities. viewed on November, 15, 2022.
- WILLIAMS, H. 2021. The meaning of "Phenomenology": Qualitative and philosophical phenomenological research methods. *The Qualitative Report*, 26, 366-385.
- ZÜLL, C. 2016. Open-ended questions (version 2.0).