








NARRATIVE/SYSTEMATIC REVIEWS/META-ANALYSIS

Digital Healthcare Tools in Nigeria: Strengthening Public Health and Pandemic Preparedness—Insights from the COVID-19 Crisis

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Abstract

Objectives: This narrative review explores the transformative impact of digital healthcare tools in Nigeria's healthcare system, particularly emphasizing lessons learned from the COVID-19 pandemic. Nigeria, a country grappling with healthcare disparities and limited access, has seen digital healthcare tools play a crucial role in enhancing public health and pandemic preparedness.

Methodology and Results: This review begins by setting the stage for the relevance of digital healthcare tools in Nigeria, acknowledging the country's complex healthcare challenges. It outlines its objectives and research approach, ensuring transparency and precision in source selection, including Nigerian databases. Examining digital healthcare tools in Nigeria highlights their potential to address healthcare access issues. This review also delves into the regulatory framework governing telemedicine in Nigeria, recognizing the need for a delicate balance between regulation and innovation, given the nation's unique infrastructure challenges. This provides insights into the factors influencing telemedicine adoption among healthcare providers and patients in Nigeria. While acknowledging challenges like infrastructure limitations and regulatory complexities, this review also identifies opportunities, such as improved healthcare accessibility and cost-efficiency, brought about by digital healthcare tools in Nigeria. Concrete examples of successful digital healthcare initiatives are presented, offering actionable insights and a roadmap for future endeavors.

Conclusions: This review concludes by emphasizing the essential role of digital healthcare tools in addressing Nigeria's healthcare challenges and providing tailored recommendations for policymakers, healthcare providers, and researchers. Ultimately, this comprehensive exploration goes beyond current achievements and challenges, envisioning a future where digital healthcare tools revolutionize Nigeria's healthcare landscape, identifying promising research avenues, and anticipating innovations that can better shape the nation's healthcare.

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The emergence of the COVID-19 pandemic in late 2019 brought about an unprecedented global crisis, testing the resilience and adaptability of healthcare systems worldwide.¹ Consequently, Nigeria, regarded as the giant of Africa with over 200 million people, faced the challenge of addressing the pandemic's impact on an

already burdened healthcare infrastructure. Amid this crisis, the significance of digital healthcare tools has come to the forefront as essential instruments for strengthening public health and pandemic preparedness.²

The COVID-19 pandemic, caused by the viral pathogen SARS-CoV-2, unleashed a wave of challenges upon

healthcare systems worldwide.^{3,4} The virus spread rapidly, overwhelming healthcare facilities, depleting medical resources, and posing grave risks to healthcare professionals and the general population.^{5,6} In Nigeria, where healthcare disparities and infrastructure limitations were already evident, the pandemic laid bare the need for digital health solutions to help tackle the healthcare crisis.

In response to these challenges, digital healthcare tools have emerged as invaluable assets in Nigeria's fight against COVID-19, pivotal in addressing the multifaceted challenges posed by the pandemic. These tools encompass a broad spectrum of technologies and applications, including telemedicine, health information systems, mobile health apps, data analytics, and many more.^{7,8} Their importance in pandemic response can be understood through several vital facets: First, telemedicine, which has evolved beyond video appointments to encompass remote tracking, virtual post-visit check-ins, mental health sessions, and electronic prescription issuance,⁹ has proven to be a vital component of healthcare delivery during the pandemic.^{10,11} It facilitates remote consultations between patients and healthcare providers, ensuring continuity of care for chronic conditions and extending healthcare access to underserved areas.¹²⁻¹⁴ By reducing the need for in-person visits, telemedicine mitigates the risk of disease transmission and transforms the healthcare landscape by making services more accessible and convenient.¹⁵ With the influx of COVID-19 cases, efficient health information systems have been essential in tracking and monitoring patient information, enabling timely interventions, and supporting epidemiological research. Moreover, mobile health apps have empowered individuals to monitor their health, access information, and seek guidance remotely. These apps have been instrumental in disseminating public health information, offering symptom tracking, providing telehealth services, and enhancing healthcare accessibility and patient engagement. In conclusion, the COVID-19 pandemic has underscored the critical importance of digital healthcare tools in Nigeria's public health landscape. As Nigeria grapples with the ongoing pandemic and prepares for future healthcare challenges, these tools remain indispensable. This research seeks to delve deeply into the specific applications, challenges, and opportunities presented by digital healthcare tools in Nigeria, shedding light on their vital role in strengthening public health and enhancing pandemic preparedness in the face of unprecedented global health crises.

Telemedicine's Potential To Revolutionize Remote Healthcare In Nigeria

Telemedicine, a groundbreaking facet of digital healthcare, holds immense potential to revolutionize remote healthcare in Nigeria.¹⁶ Given its ability to bridge geographical gaps, improve healthcare access, and enhance patient outcomes, telemedicine is poised to transform the nation's

healthcare landscape.^{15,16} In a country like Nigeria, where healthcare facilities are often concentrated in urban centers, telemedicine provides a lifeline to those in remote communities, ensuring they have access to specialist healthcare services. Telemedicine can connect patients with specialists nationwide, reducing the need for referrals and long waiting times.¹⁵ Patients can receive timely consultations from experts, improving diagnostic accuracy and treatment plans.¹⁵ Expanded access to specialized care can be critical in managing chronic conditions and serious illnesses.¹²⁻¹⁴ Moreover, timely medical intervention is crucial for positive health outcomes. Telemedicine allows swift access to healthcare providers, facilitating early diagnosis and intervention. This is particularly essential in cases where early detection is vital, such as emergencies or acute illnesses, where telemedicine can significantly improve patient prognosis. Furthermore, the cost of healthcare, including travel expenses and time away from work, can be a significant burden for many Nigerians. However, telemedicine offers a cost-effective alternative.¹⁴ Patients can consult with healthcare providers from their homes, eliminating the need for travel and associated expenses. This not only benefits individuals but also reduces the strain on healthcare resources.

The COVID-19 pandemic highlighted the importance of telemedicine in pandemic preparedness. Telemedicine allows for the continuation of healthcare services while minimizing the risk of disease transmission. It also played a vital role in triaging and monitoring COVID-19 cases.¹⁷ As Nigeria prepares for potential future health crises, telemedicine will be a key tool in maintaining healthcare continuity. Nevertheless, it is important to note that while telemedicine offers immense promise, several challenges must be addressed for its widespread adoption in Nigeria. These challenges include ensuring reliable internet connectivity, addressing data privacy concerns, and training healthcare professionals in telemedicine practices. Additionally, regulatory frameworks must be adapted to support and govern telemedicine services effectively.

Internet Resources For Health Information

In Nigeria, as technology advances, more people are gaining access to the internet.^{18,19} This access to the internet provides valuable resources, including health information, to patients who are connected online. When patients have access to online health information, they often have higher expectations for their healthcare. Studies show that online health information can influence patients' decisions about their healthcare providers.^{18,20} Patients who use online health information may change their lifestyles, like adjusting their diet, increasing physical activity, scheduling doctor appointments, and seeking more information about their treatments and diagnoses.¹⁸ Access to the internet is believed to enhance patients' understanding of complex medical concepts, ultimately improving public health

outcomes.²¹ Internet-based health information can also strengthen disease prevention strategies and encourage individuals to be more proactive about their health.^{21–23}

In the context of Nigeria's healthcare system and its preparedness for future pandemics, there is a pressing concern regarding the reliability and credibility of online health information.²⁴ This issue is significant because having access to accurate and trustworthy health information is crucial in a healthcare system's readiness to respond to pandemics. Ensuring that online information is up-to-date, and credible is essential for building trust in online health resources.¹⁹ As Nigeria works on strengthening its healthcare system and preparedness for future pandemics, it is essential to address the challenge of ensuring that the health information accessible via the internet is reliable. Patients and healthcare providers should be encouraged to collaborate in selecting trustworthy online health information resources to improve the country's overall healthcare resilience.

Mobile Health (Mhealth): Healthcare In Your Pocket

In the context of Nigeria's healthcare system and its preparedness for future pandemics, MHealth, or mobile health, holds significant promise. This technology offers benefits that can strengthen healthcare professionals and the general population in Nigeria. Examples include using mobile phone applications in consultation, monitoring blood sugar levels, oximetry, blood pressure, and more. Moreover, we have different mHealth applications in Nigeria, such as Mobidoc and Kangpe, that allow patients to seek medical advice from seasoned health practitioners.

For healthcare professionals and students in medical education, MHealth applications have demonstrated their effectiveness in enhancing learning and skill development. This is particularly valuable in a country like Nigeria, where a well-trained healthcare workforce is crucial for pandemic preparedness.²⁵ The efficiency of healthcare workers in Nigerian hospitals and public healthcare settings can be notably improved by adopting MHealth tools. On May 15, 2023, the Nigerian Communications Satellite Limited (NIGCOMSAT), in collaboration with Ethnomet and Sawtrax, launched NIGCOMHEALTH, a groundbreaking telehealth platform in Nigeria. This revolutionary platform allows Nigerians to schedule medical appointments, access professional medical guidance, and consult healthcare experts from diverse locations, whether at home, in the office, at school, or within their local communities. Additionally, NIGCOMHEALTH is easily accessible through mobile devices. This telehealth initiative signifies a significant leap in improving healthcare accessibility throughout Nigeria, allowing individuals to access medical care and guidance without needing to visit healthcare facilities physically. This development is vital in ensuring consistent and safe healthcare delivery

and adapting to the evolving healthcare landscape. These applications can streamline various healthcare processes, ultimately contributing to better patient care, diagnosis, and treatment, which are essential aspects of pandemic preparedness.^{25,26}

In the realm of chronic disease management, MHealth plays a pivotal role. Chronic conditions like asthma, heart failure, and lung disease are prevalent in Nigeria. MHealth can significantly improve the management of these conditions, leading to better patient outcomes, reduced mortality rates, and enhanced overall quality of life.²⁷ One critical aspect of pandemic preparedness is effective communication between patients and healthcare providers. MHealth applications facilitate this communication by enabling remote consultations, continuous remote monitoring of health conditions such as blood glucose, and timely intervention. This can be particularly vital during a pandemic when healthcare facilities might face increased pressure.²⁷ Moreover, improved medication adherence, as observed in tuberculosis and HIV patients using MHealth services, can lead to better clinical outcomes. Timely diagnosis and treatment, facilitated by MHealth, can also help in the early detection and containment of infectious diseases, a crucial aspect of the pandemic response.^{27,28} Beyond clinical applications, MHealth has been instrumental in collecting community data and supporting public health surveillance efforts. In a country, as vast and diverse as Nigeria, this can aid in tracking and responding to potential outbreaks effectively.^{29,30} Nigeria faces healthcare resource challenges, particularly in remote or underserved areas. MHealth can help bridge these gaps, promoting health equity by expanding access to healthcare services. This is especially important for pandemic preparedness, as equitable access to healthcare resources is vital in responding to public health emergencies.³¹ There is broad adoption of mHealth apps and services on a national scale as many countries have continued to use these apps for monitoring, patient counseling, and other healthcare services since the COVID-19 pandemic.³²

Leveraging Big Data For Enhanced Pandemic Preparedness In Nigeria's Healthcare System

Like many other parts of the world, Nigeria's healthcare system confronts substantial challenges.³² These range from limited resources to the rapid expansion of the population.³³ Consequently, there is a constant need for innovative solutions. Big data, with its distinct attributes that include volume, variety, velocity, veracity, and value,²¹ present a transformative opportunity to fortify Nigeria's healthcare system and enhance its readiness for future pandemics. Big data technology plays a pivotal role in facilitating various essential healthcare functions. These encompass aiding clinical decision-making, overseeing population health, and closely monitoring disease

trends.³⁴ Moreover, it can potentially be a vital tool in epidemic prevention and control.³⁵ In the context of Nigeria, where the healthcare system faces significant challenges, the utilization of big data in healthcare can contribute significantly. In Nigeria, startups, such as LifeBank and Omomi, harness the power of big data to make well-informed decisions. This strategic use of big data empowers startups. For example, LifeBank effectively employs big data to track the availability and distribution of blood and various medical supplies nationwide. It leverages data analytics to optimize the delivery of these vital resources to hospitals and patients in need. Omomi, on the other hand, leverages big data to provide parents with valuable access to health-related information and services for their children. Furthermore, Omomi utilizes data analytics to monitor children's immunization status, growth, and development while offering personalized health advice and reminders. Big data can enable timely detection and reporting of cases, enhance the likelihood of swiftly identifying diagnostic and treatment methods, and optimize hospital management efficiency.²¹

China's experiences leveraging big data in healthcare, particularly during the COVID-19 pandemic, offer valuable lessons for Nigeria. China's approach involved relying on infectious disease case data reports for early warning and monitoring²¹ and actively advancing the informatization of medical institutions. These included systematically storing medical services-related information in computer network systems and accumulating extensive medical service data.²¹ China's response was further strengthened by its proactive stance in the aftermath of the severe acute respiratory syndrome (SARS) outbreak in 2003.²¹ The Chinese government formulated plans to identify the early signs of infectious diseases promptly, and it enacted regulations, such as the Emergency Regulations for Public Health Emergencies, requiring units that identify infectious diseases to report them promptly.²¹

One noteworthy initiative was implementing a national monitoring system in China in March 2020.²¹ This system utilized mobile phone positioning data to generate quick medical response codes reflecting an individual's health status.²¹ To obtain a code, citizens were required to provide personal information, including their name, national identity number or passport number, and phone number.²¹ The implications are clear: big data technology harbors immense promise for a profound transformation of Nigeria's healthcare system. It offers an opportunity to address existing challenges effectively and enhance the country's preparedness for future pandemics. Learning from the experiences of countries like China, which have successfully harnessed the power of big data in healthcare, can provide valuable insights and guidance as Nigeria seeks to harness the potential of this technology for the betterment of its healthcare landscape.

Blockchain Technology: Reinventing Healthcare Security And Transparency In Nigeria

In the context of Nigeria's healthcare system, which faces numerous challenges, including limited resources and rapid population growth,^{36,37} the integration of blockchain technology holds immense potential for addressing critical issues and improving healthcare outcomes. One of the most significant advantages blockchain can offer Nigeria's healthcare system is enhanced data security.³⁸ Traditional healthcare data systems in the country are often vulnerable to breaches and unauthorized access, which can lead to significant privacy and security concerns.^{36,39} Furthermore, the Nigerian government has initiated efforts to craft a comprehensive blockchain regulatory framework, a step outlined in the draft National Blockchain Policy unveiled by the National Information Technology Development Agency (NITDA) in 2021. By implementing blockchain, Nigeria can establish a highly secure and tamper-proof infrastructure for storing and managing patient records and medical information. This would ensure that sensitive data remain confidential and accessed only by authorized individuals, thereby mitigating data breaches and privacy violations.^{36,39} Moreover, the immutable nature of blockchain is crucial in preserving the accuracy and integrity of healthcare data.³⁹

In a country where reliable and unaltered medical records are paramount for providing effective patient care, blockchain can guarantee that it cannot be altered or tampered with once data are recorded.³⁹ This feature ensures that patient records and treatment histories remain trustworthy, which is vital for healthcare providers and patients. Nigeria's healthcare system would also benefit from the decentralized aspect of blockchain technology. Unlike traditional centralized databases susceptible to single points of failure, blockchain operates on a decentralized network of nodes.^{36,37,39} This means that the entire system's integrity remains intact even if one node fails or is compromised. This decentralized structure adds a layer of resilience and security, particularly valuable in a healthcare environment where data loss or corruption can have life-threatening consequences.

Transparency, another core attribute of blockchain, can help cultivate trust within Nigeria's healthcare ecosystem. Patients, healthcare providers, and regulatory bodies can independently verify the accuracy and history of healthcare data, fostering confidence in the system. This transparency can improve doctor-patient relationships, reduce medical errors, and better accountability across the healthcare sector.

Real-world applications of blockchain during health crises, such as the COVID-19 pandemic, illustrate how Nigeria could benefit. Blockchain-enabled systems could securely monitor vaccine distribution, verify the authenticity of pharmaceuticals, and facilitate contact tracing

while protecting individual privacy.³⁷ These applications would contribute to better pandemic response and control in Nigeria, ensuring the safe and efficient delivery of healthcare services during challenging times. Furthermore, blockchain can facilitate secure data exchange among healthcare researchers in Nigeria, promoting collaboration and accelerating medical research efforts. This would enable the country to stay at the forefront of healthcare innovation and contribute valuable insights to global health challenges. Integrating blockchain technology into Nigeria's healthcare system has the potential to revolutionize the way healthcare data are managed, secured, and shared.

Nigeria has proactively embraced a range of digital applications across various sectors. Leading the charge, the Nigerian Identity Management Commission (NIMC) is spearheading the development of an electronic identification solution, streamlining Nigerians' access to their National Identification Number (NIN) online. In tandem, the Nigerian Ports Authority (NPA) has implemented a web-based platform to meticulously oversee and enhance the flow of goods within Nigerian ports, effectively reducing fraudulent activities and elevating transparency. A significant stride is the Central Bank of Nigeria (CBN) initiative to introduce the eNaira, a digital currency poised to revolutionize payment systems nationwide. Despite these commendable advancements, Nigeria faced a security challenge, notably in 2021, when a significant data breach incident unfolded. This breach led to the unauthorized exposure of personal information from over 4 million Nigerians. It originated from a third-party mobile application that collected NINs without proper authorization and security measures. Nigeria took a pivotal step in security and privacy regulations by implementing the Nigerian Data Protection Regulation (NDPR) in 2019. This regulatory framework closely aligns with the General Data Protection Regulation, underscoring the responsibility of organizations to safeguard personal data. By tackling data security, integrity, and transparency issues, blockchain technology can significantly enhance patient care, elevate healthcare outcomes, and better equip Nigeria for future health crises. It is an innovative solution in harmony with the country's healthcare needs and challenges, ultimately strengthening and revitalizing the healthcare system.

Electronic Health Records: Ensuring Seamless Data Management

Electronic Health Records (EHRs) are a comprehensive and longitudinal collection of patient and healthcare data, encompassing various aspects of a patient's health beyond just medical treatment.⁴⁰ Recently, EHRs have gained substantial significance, with multinational companies and governments adopting EHRs to facilitate

patterns of patient care.⁴¹ Transmission of information between healthcare facilities has notably improved due to EHRs.⁴² These records are now used by primary care physicians, hospitals, insurance companies, and patients, signifying widespread acceptance among medical practitioners.⁴³ Primary care examination rooms, for instance, utilize EHRs to access previously documented patient records and aid decision-making, shifting the focus from physical patient-clinician interactions to virtual consultations and telemedicine.⁴⁴ Similarly, EHRs have advanced digital pathology and lab results integration.⁴⁵

A study involving 35 trained healthcare professionals in Nigeria revealed that EHRs offer advantages and challenges within the healthcare system.⁴⁶ In studies conducted in two Nigerian hospitals, the benefits of EHRs included significant reductions in transcription costs, paperwork, administrative expenses, and errors.^{46,47} EHRs proved effective in data capture, offering additional services, ensuring timely information access, and facilitating research.^{46,47} These findings suggest that EHRs hold the potential to enhance healthcare management in Nigeria significantly.

Challenges associated with EHRs in Nigeria have become apparent.⁴⁶ These challenges encompass concerns regarding patient privacy, inadequate internet connectivity, information overload, power interruptions, and data completeness and accuracy issues.⁴⁶ Addressing these challenges requires further investment and the development of solutions.

A noteworthy advantage of EHRs is their compatibility with mobile devices equipped with cameras, allowing clinicians to easily capture and store patient information, contributing to widespread utilization.⁴⁸ The EHRs exhibit a structured approach, with three identified components: time-oriented, problem-oriented, and source-oriented EHRs. Time-oriented EHRs organize data chronologically, while problem-oriented EHRs present patient data in the SOAP (Subjective, Objective, Assessment, and Plan) format. Source-oriented EHRs focus on tracking the origin of the data, emphasizing data credibility through source verification.⁴⁹ In the context of the COVID-19 pandemic, the emergence of EHR data significantly contributed to increased research on the virus.

Many hospitals employ EHRs to develop databases related to COVID-19. These databases are essential for analyzing COVID-19 through statistics and machine learning algorithms, facilitated by introducing new diagnosis codes and lab tests.⁵⁰ Numerous healthcare organizations have embraced EHR adoption. For instance, in Iran, the Iranian Ministry of Health and Medical Education (MOHME) established a framework for electronically aggregating health data, with every point of care unit equipped for this purpose.⁵¹ Academic medical centers have been at the forefront of EHR research, and

various agencies, including health agencies, information technology companies, academic medical centers, and professional societies, have utilized EHRs during the COVID-19 pandemic to gather critical data.^{52,53} The incorporation of EHRs into Nigeria's healthcare system offers substantial potential, particularly concerning its readiness for future pandemics. Adopting a unified national EHR system presents an efficient solution that can save time and resources. These records can enhance data collection, research, and decision-making,^{44,45,46,48,49} thereby bolstering the healthcare infrastructure and its responsiveness during health crises. However, the current state of EHRs reveals that they have yet to achieve full interoperability or extensive utilization for populating databases.⁴⁶ While ongoing efforts are in place to enhance this interoperability, it remains a prospect for future development and a recommended course of action for the healthcare system. The healthcare industry acknowledges the potential for seamless integration of EHRs with databases, and work is underway to make this vision a reality, even though it has yet to be fully realized.

Challenges and Barriers To Digital Health Adoption

The significance of digital healthcare cannot be overstated; it represents a significant advancement in medicine. Nevertheless, digital healthcare encounters several obstacles that hinder its progress. Efforts have been made in public health to address the challenges posed by COVID-19. These impediments have had a considerable impact on healthcare, necessitating their resolution.⁵⁴ The pandemic has sparked heightened interest in telemedicine and telepharmacy. Despite the increased adoption of COVID-19 screening and home delivery of medicines, there remains a critical issue: poor internet connectivity.⁵⁵ This problem is exacerbated by network connections and power supply instability, particularly in many rural areas. Consequently, a digital divide has emerged, separating those with internet access from those without. COVID-19 placed immense pressure on healthcare systems in emerging and low-income countries.⁵⁶ However, measures such as social distancing drove the adoption of digital health as an alternative to physical gatherings and activities. Yet, this shift had significant financial implications, leading to another challenge. A notable 76.4% of respondents in a research study expressed their inability to afford digital healthcare.⁵⁷ Additionally, the quality of remuneration and incentives remains a concern.⁵⁸ Digital health is considered burdensome, and adequate incentives are needed to drive its adoption.

In conjunction with financial challenges, a lack of technical know-how has been identified as a problem. Proficiency is required to install and operate the necessary software.⁵⁹ This issue is compounded by a need for more awareness about telemedicine, affecting both healthcare

providers and patients. A survey of medical officers and nurses supported this point, revealing a knowledge gap among healthcare providers and patients.⁶⁰ Moreover, reports indicate that there is currently no regulatory framework to govern and implement digital healthcare.⁶¹ In Nigeria, efforts are underway to address this issue. The NITDA, the Ministry of Health, and the Ministry of Communications are collaborating with entrepreneurs interested in health technology to develop a policy document.⁶² This will help ensure that digital healthcare operates within the required boundaries, instilling confidence and trust among the population. These challenges demand solutions, and a positive attitude is crucial in addressing them. Davies' Technology Model from 1989 emphasized that one's intention to use technology is influenced by one's attitude toward it and perception of its usefulness.⁶³ Efforts should focus on improving access to fast and reliable internet, particularly in rural areas. Extensive resources should be allocated to educate the public about digital healthcare. This is essential as digital healthcare is viewed as a frontline defense strategy against COVID-19, helping reduce exposure and control its spread among healthcare workers and patients.

Strategies For Successful Digital Health Implementation

The emergence of digital health solutions has revolutionized healthcare across the globe, offering the promise of improved access, efficiency, and patient outcomes. In Nigeria, a nation of over 200 million people adopting digital health technologies presents a unique opportunity to address longstanding healthcare challenges and prepare for future health crises. A holistic approach is essential for successful digital health implementation in Nigeria, encompassing the following issues.

Government Support and Policy Framework

One of the cornerstones of successful digital health implementation is the development of comprehensive policies and regulations.⁶⁴ The Nigerian government must establish a robust policy framework that governs digital health adoption, emphasizing data security, privacy, and interoperability. Moreover, allocating budgetary resources and offering incentives can encourage healthcare institutions and professionals to embrace digital health solutions.⁶⁵ Collaborations with international organizations and partners can provide valuable insights and best practices in digital health policy development.⁶⁶

Healthcare Infrastructure Enhancement

A reliable healthcare infrastructure forms the backbone of digital health implementation. Nigeria must invest in improving healthcare infrastructure, focusing on expanding access to stable internet connectivity, even in remote

and underserved areas. The development of telecommunication networks and the assurance of a consistent power supply are critical to support the functionality of digital health tools.⁶⁵

Healthcare Workforce Training

Digital health adoption relies on a proficient healthcare workforce. Training programs should be designed to ensure that healthcare professionals are well-versed in using digital health technologies effectively.³⁵ Collaboration with educational institutions can integrate digital health courses into medical and nursing curricula, ensuring that the next generation of healthcare providers is equipped with the necessary skills. Encouraging continuous professional development in digital health is also vital.⁵²

Digital Health Awareness and Education

Public awareness is essential for successfully adopting digital health.^{21,35} Nationwide awareness campaigns can educate the population about the benefits and safe usage of digital health tools. Simultaneously, health literacy programs should be promoted to empower patients to engage actively in their healthcare using digital resources.

Interoperability Standards

Standardization is crucial for ensuring that different digital health systems can communicate seamlessly. Nigeria should implement standardized protocols and interoperability frameworks that encourage vendors to adopt these standards in their solutions. This approach ensures that data can flow freely and securely across various healthcare platforms.^{36,37}

Telemedicine Expansion

Telemedicine, a vital component of digital health, should be developed and expanded, especially in remote and underserved areas.^{16,17,18,19,67} This expansion enhances access to healthcare services and supports routine consultations, specialist referrals, and follow-up care, particularly in times of crisis.

Mobile Health (mHealth) Initiatives

Leveraging the widespread use of mobile phones is pivotal.²⁵⁻²⁷ Nigeria can develop mobile health apps that cater to specific healthcare needs, such as appointment scheduling, medication reminders, and health monitoring. These apps can bridge gaps in healthcare delivery and improve patient engagement.^{26,27}

Data Security and Privacy

Prioritizing data security and privacy is non-negotiable. Nigeria must implement robust encryption, access controls, and compliance with international data protection standards to safeguard patient information. The

establishment of data protection agencies can oversee compliance and address data breaches swiftly.^{36,37,40,41,42}

Collaboration and Partnerships

Effective collaboration among government agencies, healthcare institutions, technology providers, and international organizations is paramount. Private sector partnerships can drive innovation and investment in digital health solutions, fostering a thriving digital health ecosystem.

Monitoring and Evaluation

A comprehensive monitoring and evaluation system should be implemented to gauge the effectiveness and impact of digital health initiatives. Regular assessments should measure healthcare provider and patient satisfaction, facilitating continuous improvement of digital health services.^{38,39}

Community Engagement

Engaging local communities and traditional leaders is vital for promoting digital health acceptance and dispelling misconceptions.^{19,21-23} Gathering community feedback helps tailor digital health solutions to their specific needs and preferences, ensuring relevance and effectiveness.

Research and Development

Encouraging local research and development in digital health fosters innovation. Nigeria should invest in initiatives that drive innovation, create solutions tailored to its unique healthcare challenges, and contribute to the global advancement of digital health.

Discussion

Digital health in Nigeria holds significant promise in addressing healthcare challenges, especially considering the country's demographic and technological landscape. With Nigeria's unique blend of urban and rural populations and the concentration of healthcare facilities in urban areas, the adoption of digital health solutions takes on particular importance in a nation where 53.8% of the population resides in bustling urban centers, while 46.2% call rural areas home,⁶⁸ and the chasm between access to healthcare resources becomes apparent.

Telemedicine emerges as a pivotal tool to bridge these geographical disparities. It enables individuals in remote communities to access specialized healthcare services through remote consultations with healthcare providers. This form of telehealth brings the doctor's office to the doorstep of those previously underserved. Moreover, Nigeria's population structure presents distinct healthcare challenges due to the lack of government funding.⁶⁹ Government contributions to the healthcare sector remain significantly inadequate. These challenges have contributed to Nigeria's ranking as a country with one

of the worst healthcare systems globally, primarily due to poor funding and resource allocation.⁶⁹ As a consequence of this dire situation, successive administrations have demonstrated a lack of resolve in addressing these deficiencies. This persistent underfunding and its associated consequences have exacerbated the existing issue of brain drain within the healthcare system. Skilled healthcare practitioners, disillusioned by the challenges and low resource availability, seek opportunities elsewhere, leading to a shortage of professionals willing to embrace and utilize digital health tools to improve the country's healthcare landscape.

Integrating EHRs into Nigeria's healthcare system is pivotal for efficient data management. As the population burgeons, EHRs enable the seamless exchange of patient information between healthcare facilities, ensuring that healthcare providers can access patient records when needed. This enhances decision-making and patient care, which is particularly valuable in Nigeria, a country experiencing rapid population growth. Despite these promising strides, Nigeria faces unique challenges in its digital health journey, with inconsistency in power supply presenting a notable hurdle. While 55.4% of the population had internet access at the start of 2023, a substantial 44.6% remained offline,⁶⁸ underlining the pressing need to bridge this digital divide.

The inconsistency of power supply in Nigeria further complicates the accessibility and reliability of digital health services, especially in rural areas where power interruptions are more frequent. Nonetheless, as of the beginning of 2023, Nigeria's median mobile internet speed via cellular networks stood at 19.84 Mbps, providing a foundation for mobile health apps to deliver valuable health information, reminders, and even telemedicine consultations. While making notable progress in urban areas with internet access, these digital health tools require further expansion and enhancements in accessibility and reliability, including concerted efforts to provide a steady power supply. Nigeria's commitment to expanding connectivity, improving internet speeds, and reducing the digital divide becomes paramount in this evolving landscape. These endeavors are vital to ensure that the benefits of digital health reach all segments of the population, contributing to a more equitable and resilient healthcare system.

Conclusion

Nigeria's healthcare system faces challenges due to limited resources and rapid population growth. Innovative technologies, including big data, blockchain, and EHRs, offer opportunities to strengthen the system and enhance readiness for future pandemics. Big data offer transformative potential with its vast volume, variety, velocity, veracity, and value. It can aid clinical decision-making,

monitor population health, and track disease trends. Nigeria can use big data to detect cases promptly, swiftly identify diagnostic and treatment methods, and optimize hospital management, enhancing preparedness for future health crises.

Blockchain technology can revolutionize data security and transparency in Nigeria's healthcare system, providing a highly secure and tamper-proof infrastructure for patient records. The decentralized nature of blockchain ensures data integrity, even in the face of system failures. Its transparency fosters trust, leading to better doctor-patient relationships and reduced medical errors. The technology's real-world applications, such as secure vaccine monitoring and contact tracing during health crises, offer further benefits. The integration of EHRs is crucial for efficient data management. Nigeria's growing population requires timely data exchange between healthcare facilities. A unified national EHR system can strengthen the healthcare infrastructure and improve the response to health crises.

Despite the promise of digital health, Nigeria faces challenges such as poor internet connectivity, financial constraints, and a lack of technical know-how. Regulatory frameworks and policies are being developed to address these issues and promote digital health adoption. To implement digital health successfully, Nigeria should focus on government support and policy development, improving healthcare infrastructure, training the healthcare workforce, raising awareness, setting interoperability standards, expanding telemedicine, embracing mobile health initiatives, prioritizing data security and privacy, fostering collaboration, monitoring progress, engaging with communities, and investing in research and development. Digital health technologies offer Nigeria the potential to revolutionize its healthcare system. Collaboration, government support, and comprehensive planning are essential. Nigeria's commitment to expanding connectivity, improving internet speeds, and reducing the digital divide is crucial to ensuring equitable access to digital health benefits and creating a more resilient healthcare system.

Nigeria stands at the threshold of a digital health transformation that can revolutionize healthcare access and outcomes for its vast population. Successful digital health implementation requires a collaborative effort from multiple stakeholders, including the government, healthcare providers, technology companies, and the community. By addressing infrastructure gaps, ensuring data security, and promoting education and awareness, Nigeria can harness the transformative potential of digital health, paving the way for a healthier and more resilient nation.

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Contributors

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