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Strengthening HIV Disease Surveillance in Abuja, Nigeria: Leveraging digital health innovations for real-time monitoring and response

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Abstract

Introduction: Abuja, Nigeria, has a serious HIV pandemic amid high urban density, with 1.9 million individuals living with HIV. Traditional paper-based surveillance is insufficient for tracking quick transmission, whereas digital methods like electronic reporting, GIS mapping, and AI-driven models allow real-time monitoring and enhanced data accuracy. Yet, constraints like as infrastructure restrictions, interoperability problems, limited human resources, and data security concerns hamper full-scale application. This paper investigates these digital technologies to increase HIV monitoring in Abuja and presents policy suggestions for optimal incorporation into public health policies.

Materials and Methods: This research adopted a PRISMA-compliant systematic review to achieve a controlled and exact investigation. Multiple electronic databases including Web of Science, Scopus, IEEE Xplore, ACM Digital Library, and Google Scholar were searched using Boolean operators with terms such as "HIV disease surveillance," "digital health innovations," "electronic reporting system," "geospatial mapping," and "AI-driven perspective modelling." Inclusion criteria centred on peer-reviewed journal articles, conference proceedings, and book chapters published in English between 2011 and 2021, whereas opinion pieces and research unrelated to the primary emphasis were removed. An initial pool of 1,519 papers was reduced to 1,143 after eliminating duplicates, and additional title, abstract, and full-text evaluations by independent reviewers further restricted the pool to 154 final sources. Data from these studies were retrieved using a standardized pro forma and analyzed by theme and narrative synthesis, with study quality validated via the CASP checklist and MMAT, and inter-rater reliability guaranteed using Cohen's κ coefficient and consensus discussions.

Results: HIV disease surveillance includes the systematic gathering, analysis, and interpretation of data to monitor transmission patterns, assess treatments, and drive public health policy. Traditional approaches in Nigeria such as case reporting, sentinel monitoring, and behavioral surveys have produced useful insights but are sometimes constrained by delayed reporting and inadequate data. The integration of digital health technology, including electronic reporting systems, GIS mapping, and AI-driven predictive modeling, offers real-time monitoring, better accuracy, and more effective resource allocation, particularly in high-density metropolitan areas like Abuja. Despite these developments, problems like as infrastructure restrictions, interoperability issues, and data security concerns remain important impediments. Nigeria's comprehensive surveillance plan, which includes utilizes integrated biological and behavioral surveys and modern infection testing algorithms, intends to solve these difficulties and increase targeted measures for reducing the HIV pandemic.

Discussion: HIV monitoring in Abuja confronts severe problems, including insufficient budget, inadequate access to care for high-risk groups, geographical inequities, fast changing demographics, and fragmented data systems owing to poor stakeholder cooperation. These challenges have typically prevented timely and reliable data gathering, important for successful HIV care. Digital health innovations such as electronic reporting systems, mobile health apps, GIS mapping, and AI-driven analytics offer promise advances by allowing real-time monitoring and increased data accuracy.

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However, its adoption is limited by infrastructure shortcomings, insufficient digital literacy among healthcare professionals and patients, high prices, and data security issues. To overcome these challenges, strategies such as strengthening data management systems (e.g., using DHIS2), integrating mobile health technologies, building capacity through training, enhancing community engagement, ensuring robust data privacy measures, and securing sustainable financing are proposed. These combined approaches seek to develop a more responsive and effective HIV monitoring system in Abuja, eventually leading to improved public health outcomes.

Conclusion: Utilizing digital health technologies gives a unique potential to increase HIV disease monitoring in Abuja. By solving implementation issues and supporting supportive policies, Abuja may establish a more responsive and data-driven HIV monitoring system. Future research and sustained investment in technology-driven solutions will be vital for attaining lasting public health gains in HIV management

Keywords: HIV disease surveillance; Digital health innovations; Electronic Reporting System; Geospatial Mapping and Ai- Driven Perspective Modelling; Health Belief Model; Technology Acceptance Model

1. Introduction

With Abuja among the most impacted areas because of its high population density and urbanisation, HIV continues to be a serious public health concern in Nigeria. With an estimated 1.9 million persons living with HIV, Nigeria has the second-largest HIV pandemic in the world, according to Joseph et al. (2020). Effective disease surveillance is critical for tracking HIV trends, detecting outbreaks, and implementing appropriate interventions. Often depending on paper-based records and delayed reporting, traditional monitoring techniques have proved insufficient in handling the dynamic character of HIV transmission and response (Haider, 2021). The incorporation of digital health technologies into surveillance systems has the potential to increase real-time monitoring and improve health outcomes.

Globally, digital health technologies including electronic reporting systems, geographical mapping, and artificial intelligence (AI)-driven predictive modelling are changing disease monitoring (World Health Organisation [WHO], 2016). Real-time data collecting and transmission made possible by electronic reporting helps to improve the accuracy of surveillance data by thereby lowering delays. By use of geospatial mapping, HIV prevalence patterns may be visualised, therefore enabling public health authorities to better allocate resources (Oluwalana, 2021). Furthermore, by use of extensive epidemiological data analysis, AI-driven models may forecast epidemics and guide focused actions. Despite these developments, the use of digital health technologies in Nigeria's HIV monitoring remains restricted owing to infrastructural, regulatory, and technological difficulties.

Across the many limitations the present surveillance system in Abuja confronts are scattered data sources, lack of interoperability across health information systems, and insufficient human resources for the application of digital health (Attah, 2017). These difficulties compromise the capacity of legislators and medical experts to make informed choices based on facts in attempts at HIV control (Adejumo, 2020). Furthermore, worries regarding data security, confidentiality, and ethical issues offer further impediments to the full-scale implementation of digital health solutions (Signé, 2020). Dealing with these problems calls for a calculated strategy including government agencies, corporate sector players, and international health organisations cooperating to enhance HIV monitoring systems.

Empirical studies have proved the value of digital health technologies in enhancing disease monitoring in many circumstances. For example, research in South Africa indicated that the adoption of electronic medical records dramatically decreased HIV reporting mistakes and increased patient follow-up rates (Khubone et al., 2020; Etoori, 2020). Similarly, an assessment of digital surveillance systems in sub-Saharan Africa emphasised the relevance of mobile health (mHealth) technology in overcoming communication gaps between healthcare practitioners and patients (Manyazewal et al., 2021; Mndeme, 2021). These results underline the potential advantages of harnessing technology to increase HIV monitoring in Nigeria. However, contextual variables such as infrastructural limits and legislative shortages must be addressed to guarantee sustainable adoption.

This research attempts to evaluate the significance of digital health technologies in increasing HIV disease surveillance in Abuja, Nigeria, with an emphasis on real-time monitoring and response. By comparing the performance of electronic reporting systems, GIS mapping, and AI-driven predictive modelling, the research intends to give insights into how digital health technologies might boost surveillance efforts. Additionally, the study will identify barriers associated with adopting these technologies and give policy suggestions for their effective integration. Understanding these dynamics will assist to strengthening HIV control efforts and improve public health decision-making in Nigeria.

1.1. Research Questions

Effective HIV disease surveillance is critical for tracking transmission trends, recognising outbreaks, and implementing appropriate interventions. Traditional monitoring techniques in Abuja, Nigeria, confront issues such as delayed reporting, fragmented data systems, and restricted access to real-time information. Digital health advancements, including electronic reporting systems, GIS mapping, and AI-driven predictive modelling, provide intriguing options for boosting monitoring efficiency. However, the degree to which these technologies may enhance HIV surveillance and response in Abuja remains underexplored. To overcome this gap, the project attempts to answer the following research questions:

- How efficient are electronic reporting methods in enhancing HIV disease monitoring in Abuja?
- What role does geospatial mapping play in monitoring HIV prevalence and response efforts?
- How might AI-driven predictive modelling boost epidemic detection and resource allocation?
- What difficulties exist in incorporating digital health technologies into HIV surveillance in Abuja?

1.2. Research Objectives

The incorporation of digital health technologies into HIV disease surveillance gives a potential to boost real-time monitoring and response activities in Abuja, Nigeria. Traditional surveillance systems can suffer from inefficiencies, including delayed data gathering, mistakes in reporting, and issues in resource allocation. As the HIV pandemic continues to represent a serious public health issue, integrating digital technologies such as electronic reporting systems, geographical mapping, and AI-driven predictive modelling might boost monitoring and improve health outcomes. This project intends to evaluate how these digital tools might increase HIV monitoring and response, enabling timely and data-driven interventions.

One main objective of this research is to analyse the efficiency of electronic reporting methods in increasing HIV disease monitoring. Paper-based reporting methods, still popular in many healthcare institutions, lead to delays in data transfer and inaccuracies in record-keeping. Digital reporting systems offer the ability to alleviate these difficulties by allowing real-time data collecting, minimising reporting mistakes, and enhancing collaboration among healthcare stakeholders. By analysing their effect, this project will give insights into the degree to which electronic reporting increases the timeliness and accuracy of HIV surveillance data in Abuja.

Another key topic is the importance of geospatial mapping in monitoring HIV prevalence and response activities. Understanding the geographic distribution of HIV cases is critical for successful intervention methods. Geospatial mapping techniques may assist depict transmission patterns, identify high-risk locations, and direct resource allocation to places with the highest need. In this project, the deployment of geospatial technologies will be studied to evaluate how they promote targeted responses and enhance decision-making processes within the HIV monitoring system in Abuja.

Furthermore, this project attempts to examine the potential of AI-driven predictive modelling in increasing epidemic detection and resource allocation. Predictive analytics can analyse massive information to anticipate trends, discover possible HIV hotspots, and improve intervention options. By harnessing artificial intelligence, healthcare practitioners may predict epidemics and distribute resources more effectively. This project will evaluate the degree to which AI-driven models can enhance the accuracy of HIV forecasts and contribute to proactive public health actions in Abuja.

Lastly, the research will highlight the barriers involved with incorporating digital health technologies into HIV monitoring. While digital solutions provide tremendous benefits, various challenges prevent their implementation, including infrastructural limits, data security concerns, and aversion to change among healthcare personnel. By identifying these problems, the research will give suggestions for overcoming impediments and guaranteeing the effective deployment of digital health technology in HIV disease monitoring.

2. Review of The Literature Sources

2.1. Understanding the Concept of HIV Disease Surveillance

HIV disease surveillance is a key public health role that includes the systematic collection, analysis, and interpretation of data linked to HIV infection and its progression. The major purpose of surveillance is to monitor trends in HIV transmission, evaluate the success of preventive and treatment programme s, and influence policy choices (Kapiriri, 2019). Effective surveillance systems help identify high-risk groups, monitor new infections, and distribute resources

effectively to regions most impacted by the illness. In many countries, including Nigeria, HIV surveillance is undertaken by several approaches, including as case reporting, sentinel surveillance, and Behavioural surveys, to offer a complete picture of the pandemic.

Traditional HIV surveillance approaches have played an important role in disease monitoring; nevertheless, they are typically hampered by delays in data reporting, missing records, and poor coverage in particular locations. Case-based surveillance, which requires obligatory reporting of confirmed HIV cases, is one of the key strategies utilised internationally (Buchbinder & Liu, 2019). While this strategy delivers useful data, its performance relies on timely and correct reporting by healthcare institutions. Additionally, sentinel monitoring, which focuses on specialised groups such as pregnant women visiting prenatal clinics, assists in identifying prevalence trends but may not completely capture the larger extent of HIV transmission (Yotebieng et al., 2019). These constraints underscore the need for more modern and efficient surveillance technologies.

The emergence of digital health technology has changed HIV monitoring by boosting real-time data collecting and analysis. Electronic health records (EHRs), geographic mapping, and artificial intelligence (AI)-driven prediction models are currently being incorporated into surveillance systems to increase accuracy and reaction time (Ahmed et al., 2020; Rong et al., 2020). Digital reporting solutions allow healthcare practitioners to communicate data instantaneously, decreasing delays and assuring more complete monitoring. Geospatial mapping techniques can display HIV prevalence in diverse places, enabling for targeted therapy. Moreover, AI-driven models may forecast epidemics and improve resource allocation, making surveillance more proactive and responsive to developing patterns (Bohr & Memarzadeh, 2020; Zeng et al., 2020).

Despite these developments, obstacles exist in the deployment of HIV monitoring systems, especially in low-resource settings. Issues such as insufficient infrastructure, low financing, and concerns about data privacy and security hamper the use of digital surveillance systems (Ogunyemi & Adesanya, 2020). In Nigeria, problems in interoperability between multiple health information systems further hinder surveillance efforts (Ibeneme et al., 2020). Additionally, healthcare personnel may need extra training to efficiently employ digital health technology, underscoring the need for capacity-building activities. Addressing these problems is critical for creating a strong monitoring system that can support successful HIV prevention and control initiatives.

Understanding the notion of HIV disease monitoring is critical for boosting public health interventions and improving outcomes for impacted communities. As the HIV pandemic advances, surveillance systems must adapt to developing technology and procedures that increase data accuracy and timeliness. The incorporation of digital health technologies has tremendous promise in overcoming conventional surveillance limits and enhancing disease monitoring. However, solving implementation issues via policy changes, infrastructure development, and personnel training is crucial for maximising the advantages of sophisticated surveillance systems. By increasing HIV disease monitoring, public health stakeholders may make informed choices that contribute to the successful control and ultimate elimination of the disease.

2.2. Importance of Real-Time Disease Surveillance in Public Health

Real-time disease surveillance plays a key role in public health by allowing the early discovery and tracking of disease outbreaks, hence promoting timely and effective interventions (Morse, 2012). Traditional surveillance systems frequently depend on delayed data collecting techniques, which might prevent prompt actions. In contrast, real-time surveillance employs digital technology to offer quick access to health data, boosting situational awareness and decision-making (Desai et al, 2019). This is especially critical in managing infectious illnesses such as HIV, where early identification of new cases and trends may assist public health authorities conduct tailored treatments to minimise transmission and improve patient outcomes (Mremi et al., 2021).

One of the key advantages of real-time monitoring is its capacity to follow illness patterns and trends more precisely (Kostkova et al., 2021). By regularly collecting and assessing data, health authorities may detect new hotspots and distribute resources effectively. For example, geographic mapping technology enables health authorities to view infection rates across various locations, ensuring that high-risk areas get appropriate medical supplies, testing kits, and healthcare professionals (Kamel Boulos & Geraghty, 2020). This proactive strategy is vital for HIV monitoring in places like Abuja, where population density and movement contribute to the spread of the illness.

Additionally, real-time monitoring boosts the efficiency of public health interventions by decreasing the time gap between data collection and action (Albahri et al., 2018). Electronic reporting systems enable healthcare professionals to submit case reports quickly, which may be pooled at national or regional levels for study (Devarapu et al., 2019). This

decreases manual data input mistakes, increases record-keeping accuracy, and guarantees that policymakers have up-to-date information for decision-making (Groseclose & Buckeridge, 2017). In the context of HIV monitoring, combining electronic health records (EHRs) with predictive analytics might assist detect possible outbreaks and improve the distribution of antiretroviral medication (ART) programmes (Gadabu, 2021).

Furthermore, real-time surveillance systems help speedy epidemic response by allowing early warning methods. Artificial intelligence (AI) and machine learning algorithms can evaluate massive information to spot anomalous increases in infections, urging rapid action. This is especially pertinent for HIV monitoring, as undetected infections and late-stage presentations remain a concern. By incorporating AI-driven monitoring systems, public health authorities may execute timely awareness campaigns, extend testing services, and improve intervention techniques to target vulnerable groups more effectively (Bohr & Memarzadeh, 2020).

In conclusion, real-time illness monitoring is vital for boosting public health responses, optimising resource allocation, and promoting data-driven decision-making. By embracing digital advances like as electronic reporting, GIS mapping, and AI-driven predictive analytics, health systems may boost their capacity to monitor and manage infectious illnesses like HIV. As Abuja and other areas attempt to enhance HIV surveillance, investing in real-time monitoring technology will be vital for attaining long-term public health objectives and lowering disease burden.

2.3. Current HIV Surveillance Approaches in Nigeria

Nigeria adopts a multimodal approach to HIV monitoring, incorporating several approaches to monitor and manage the epidemic efficiently. One of the key methods is the Sentinel Surveillance System, which has been essential in collecting complete national statistics on HIV/AIDS (Isaac et al., 2020). This technique incorporates periodic data collection from specified locations, allowing insights into HIV prevalence patterns across diverse geographies and demographics.

In recent years, Nigeria has employed improved monitoring efforts to better epidemic tracking. Notably, the adoption of HIV-1 Recent Infection Surveillance, Case-Based Surveillance (CBS), and Mortality Surveillance (MS) has proven crucial (Mremi et al., 2021). These projects attempt to detect new infections, track individual cases over time, and document HIV-related fatalities, respectively, therefore offering a more precise picture of the epidemic's dynamics.

To address the greater HIV load among important groups, Nigeria conducts Integrated Biological and Behavioural Surveillance Surveys (IBBSS) (Dongurum, 2021). These polls target populations such as female sex workers, males who have sex with men, persons who inject drugs, and transgender individuals (Vu et al., 2013). By integrating biological testing with Behavioural evaluations, IBBSS gives complete data to support targeted treatments and increase preventative efforts.

The government has also integrated Recent Infection Testing Algorithms (RITA) inside its HIV monitoring system (Negedu-Momoh et al., 2021). RITA facilitates the identification of persons who have acquired HIV lately, permitting prompt public health interventions and tailored preventive initiatives (Adedokun et al., 2020). This technique is critical for identifying transmission patterns and adopting effective control measures.

Furthermore, Nigeria adopts Capture-Recapture Methods to determine the sizes of critical populations (Adedokun et al., 2020). This approach comprises numerous sampling rounds to account for persons not caught in earlier surveys, producing more accurate population estimates. Accurate size assessment is critical for resource allocation and planning successful responses (Dongurum, 2021).

Collectively, these different surveillance tools allow Nigeria to monitor the HIV pandemic extensively, inform policy choices, and execute targeted interventions aimed at lowering transmission and improving health outcomes.

2.4. Challenges in Traditional HIV Surveillance Approaches

Traditional HIV monitoring systems have various obstacles that hamper their efficacy in tracking and controlling the pandemic (Govender & Poku, 2016). One of the key disadvantages is the dependence on paper-based data collecting and reporting methods, which are prone to delays, inaccuracies, and inefficiencies (Anyanwu et al., 2020). In many healthcare institutions, records are still manually maintained, making it difficult to assure timely and correct data input. This slows down the reporting process, resulting to delays in recognising new infections and delivering critical interventions (Bae et al., 2020).

Another key difficulty is underreporting and inadequate data, which undermines the accuracy of HIV prevalence estimations (Oster, 2010). Many persons living with HIV may not seek testing owing to stigma, fear of discrimination,

or restricted access to healthcare services (Logie et al., 2021). As a consequence, surveillance statistics may not adequately reflect the real burden of HIV in a particular community (Fauk et al., 2021). Additionally, some healthcare practitioners may fail to record all identified cases owing to poor training, lack of defined reporting protocols, or system inefficiencies, resulting to gaps in national monitoring efforts (Bogart et al., 2021).

Traditional surveillance approaches also suffer with insufficient monitoring of crucial demographics, such as sex workers, men who have sex with males, and persons who inject drugs. These populations are generally stigmatised and may shun formal healthcare facilities owing to legal and social prejudice (Fauk et al., 2021). As a consequence, HIV monitoring systems may not collect reliable data on infections among these high-risk groups, making it difficult to administer targeted therapies. The lack of integrated Behavioural monitoring accompanying biological data collecting further hinders the capacity to understand transmission patterns among these populations (Bogart et al., 2021).

Limited interoperability across multiple health information systems poses another problem in conventional HIV monitoring (Østmo, 2020). Many healthcare institutions employ distinct systems for patient records, laboratory reporting, and case monitoring, making it difficult to combine and evaluate data efficiently (Hochgesang et al., 2017). This fragmentation leads in duplication of efforts, uneven reporting, and challenges in monitoring patient outcomes over time. Without a centralised digital platform, public health authorities have difficulty in making data-driven choices for HIV prevention and treatment programmes (Wagner et al., 2019).

Lastly, budget restrictions severely influence the performance of conventional HIV monitoring programmes (Ouattara et al., 2016). Many low- and middle-income nations, like Nigeria, confront financial and logistical obstacles in maintaining an effective monitoring system. Insufficient financing for HIV monitoring leads to insufficient training of health workers, low laboratory capacity, and restricted access to modern diagnostic equipment. Additionally, unstable energy and internet access in remote regions further restrict timely data transmission and analysis, undermining the entire monitoring system (Olutuase et al., 2021).

2.5. Digital Health Innovation in Disease Surveillance

Digital health innovation in disease surveillance refers to the integration of sophisticated technology, such as electronic health records (EHRs), artificial intelligence (AI), big data analytics, and geographic mapping, to increase the monitoring, detection, and response to infectious illnesses (Golinelli et al., 2020). These technologies improve conventional surveillance approaches by enhancing data accuracy, timeliness, and accessibility, ultimately benefiting public health systems. Unlike traditional systems that depend on manual data gathering and retrospective analysis, digital health technologies provide real-time surveillance of disease trends, permitting quick actions to control epidemics and enhance healthcare delivery (World Health Organization [WHO], 2016).

The scope of digital health innovation in disease surveillance is extensive, spanning many tools and approaches meant to enhance disease monitoring (Awad et al., 2021). Electronic reporting systems, for instance, enable healthcare professionals to instantaneously submit case data, minimising reporting delays and ensuring that public health authorities receive up-to-date information for decision-making. Additionally, AI-powered predictive modelling helps early epidemic identification by examining enormous databases to discover odd patterns and risk variables. By employing machine learning algorithms, these systems can foresee possible illness spikes and drive preventive efforts to limit their effect (Morse, 2012).

Another essential part of digital health innovation is the use of geospatial mapping and geographic information systems (GIS) to depict disease prevalence and transmission patterns (; Zeng et al., 2020). These technologies assist identify high-risk locations, allowing targeted actions such as mass testing, vaccination campaigns, and resource allocation (Bohr & Memarzadeh, 2020). For instance, in HIV monitoring, GIS technology helps detect infection clusters and analyse the accessibility of healthcare facilities, ensuring that vulnerable groups get timely assistance (Boyda et al., 2019). Furthermore, mobile health (mHealth) apps enable consumers to report symptoms, obtain testing information, and get individualised health advice, boosting community involvement in disease prevention (Sleurs et al., 2019).

Digital health advances also promote interoperability and data-sharing procedures, allowing smooth integration across various health information systems. Cloud-based technologies improve data interchange across hospitals, labs, and public health authorities, removing duplication and enhancing case management (Boyda et al., 2019). This is especially critical for chronic illness surveillance, where continuous monitoring is necessary for following patient progress and improving treatment approaches (Sleurs et al., 2019). Additionally, blockchain technology is developing as a promising option to increase data security and privacy in digital surveillance, addressing problems linked to confidentiality and illegal access to sensitive health information (Esmaeilzadeh & Mirzaei, 2019).

Overall, digital health advances are revolutionising disease monitoring by boosting efficiency, accuracy, and responsiveness. By integrating cutting-edge technology, public health authorities may boost early warning systems, optimize resource allocation, and increase epidemic response tactics. As governments attempt to tackle infectious illnesses such as HIV, malaria, and COVID-19, investing in digital surveillance technologies is vital for attaining sustainable public health objectives and improving population health outcomes. The continuous advancement of these technologies will play a vital role in determining the future of disease surveillance and response globally.

2.6. Global Best Practice in Digital Surveillance for HIV

Global best practices in digital surveillance for HIV involve the integration of sophisticated technology and strategic techniques to increase the monitoring, prevention, and management of the pandemic. A cornerstone of these approaches is the introduction of electronic health information systems (Esmaeilzadeh & Mirzaei, 2019). For instance, the World Health Organization (WHO) has produced a package based on the open-source District Health Information System 2 (DHIS2) software platform (Chu et al., 2017). This system contains a Tracker programme for collecting individual and longitudinal data on persons living with HIV, encompassing features such as antiretroviral medication, viral load testing, and TB preventative therapy (Poppe et al., 2021). The linked dashboards and indicators aid users in tracking local epidemics based on case surveillance data and programmatic requirements.

Incorporating mobile health (mHealth) solutions has also proved successful. Digital technology interventions, including mHealth, eHealth, and telehealth, are developing as tools to enhance lifetime involvement in HIV care (Esmaeilzadeh & Mirzaei, 2019). These strategies enhance connection and retention in care, antiretroviral medication start and adherence, and viral suppression. Smartphones, particularly, have had great reach in resource-limited contexts, presenting considerable promise for low-cost adoption to enhance involvement in HIV care.

Real-time data analysis is another crucial component. In Ethiopia, the introduction of a digital HIV case monitoring system allows health institutions and the Ministry of Health to capture, manage, and evaluate real-time HIV surveillance data (Manyazewal et al., 2021). This approach provides for HIV risk analysis based on socio-demographic characteristics and helps identify locations with the largest number of new infections, hence permitting targeted intervention.

Furthermore, combining digital health solutions with health information systems is crucial for successful data collection, aggregation, analysis, and usage. The United States Agency for International Development (USAID) promotes the development of such systems to increase HIV pandemic control (Doyle, 2020). These integrated systems guarantee that data is routinely gathered and processed, giving a thorough picture of the pandemic and influencing strategic solutions.

Adhering to global monitoring frameworks is also necessary. UNAIDS' Global AIDS Monitoring framework offers metrics and questions for assessing progress on political declarations linked to HIV and AIDS (Manyazewal et al., 2021). Countries are urged to provide modelled HIV estimates using updated software tools by defined timeframes, guaranteeing harmonised data collecting and reporting processes.

Collectively, these best practices underline the need of harnessing digital advances to boost HIV monitoring systems. Countries can increase their ability to effectively monitor the epidemic, carry out focused interventions, and eventually strive towards controlling and eliminating HIV by putting in place electronic health information systems, mobile health interventions, real-time data analysis, integrated health information systems, and adherence to global monitoring frameworks.

2.7. Relevance of Electronic Reporting System, Geospatial Mapping and AI- Driven Perspective Modelling

Electronic reporting technologies, GIS mapping, and AI-driven predictive modelling are crucial in modernising disease monitoring, delivering greater accuracy, timeliness, and strategic foresight in public health interventions. The integration of these technologies increases the capacity of healthcare systems to identify, monitor, and react to infectious disease epidemics effectively. By integrating real-time data gathering, spatial analytics, and predictive intelligence, public health authorities may enhance decision-making processes, optimize resource allocation, and control the spread of illnesses more efficiently.

Electronic reporting systems expedite the gathering and transmission of health data by allowing healthcare professionals to input case information in real-time. This immediacy decreases delays inherent in conventional paper-based systems, enabling for fast public health actions. Digital systems such as HealthMap integrate data from diverse electronic sources to monitor global disease outbreaks, offering timely insights into emerging health hazards (Adewuyi, et al., 2021). In places with high disease loads, such as Abuja, Nigeria, electronic reporting may considerably enhance

HIV monitoring by assuring early case identification, allowing prompt treatment, and supporting data-driven policy choices.

Geospatial mapping leverages Geographic Information Systems (GIS) to show disease prevalence and transmission patterns across various geographies. By putting health data onto maps, public health authorities can detect hotspots, monitor the spread of illnesses, and allocate resources more efficiently. This geographical analysis is critical for understanding the mechanisms of illness dissemination and adopting targeted therapies (Naran et al., 2018). In the context of HIV monitoring, GIS technology helps map high-risk groups, evaluate the accessibility of healthcare resources, and improve outreach programmes to increase preventive and treatment efforts.

AI-driven predictive modelling harnesses artificial intelligence to evaluate massive datasets, discovering patterns and projecting future disease outbreaks. By analysing information from multiple sources, including social media, hospital records, and environmental data, AI models may anticipate the course of illnesses, allowing pre-emptive interventions. A study addressed the use of AI in infectious disease monitoring, stressing its potential to boost pandemic preparation (Alam et al., 2021). In HIV monitoring, AI-driven models may uncover Behavioural risk factors, anticipate possible outbreaks based on demographic trends, and assist targeted healthcare treatments to enhance patient outcomes.

Collectively, these digital techniques increase the accuracy and reactivity of disease monitoring systems. By merging electronic reporting, geospatial analysis, and AI-driven forecasts, public health authorities may spot epidemics sooner, understand their spread, and execute appropriate interventions, eventually minimising the burden of infectious illnesses on communities. As digital health advances continue to grow, their use in disease monitoring will be vital in attaining global health security and promoting public health objectives.

2.8. Theoretical Framework

This study is grounded on two theoretical scenarios; Health Belief Model and Technology Acceptance Model.

2.8.1. The Health Belief Model (HBM)

Social psychologists Irwin M. Rosenstock, Godfrey M. Hochbaum, and Stephen Kegeles devised the Health Belief Model (HBM) in the 1950s while they were working by the US Public Health Service (Champion & Skinner, 2008). It was designed to give a reason for why people did not employ disease prevention methods like TB testing. Perceived susceptibility (belief about the likelihood of contracting a disease), perceived severity (belief about the seriousness of the condition), perceived benefits (belief that taking a specific action will reduce risk), and perceived barriers (belief about obstacles preventing action) are the four main factors that the model suggests influence people's health-related behaviours (Green et al., 2020). The model was subsequently enhanced to predict health behaviours by incorporating signals to action (triggers that promote behaviour change) and self-efficacy (confidence in one's ability to act).

Numerous public health efforts, including cancer screening, HIV prevention, and vaccination campaigns, have made substantial use of the HBM. Researchers like Nancy K. Janz and Howard Leventhal have evaluated and enhanced the model over time in a range of health-related settings. Janz and Marshall H. Becker, for example, expanded its usage in the treatment of chronic illnesses by emphasising the ways in which risk perception and self-efficacy effect long-term health habits (Carpenter, 2010). Critics say that the model does not effectively take into account the social, cultural, and environmental aspects that impact health behaviours, despite the fact that it correctly describes human decision-making (Davidhizar, 1983). The HBM is still a crucial framework in behaviour change and health psychology research, despite this.

A psychological framework known as the Health Belief Model (HBM) focusses at people's beliefs of health conditions and perceived impediments to taking preventive action in order to explain health-related actions (Green et al., 2020). It argues that a person's perceived susceptibility to an illness, the perceived severity of the sickness, the perceived rewards of action, and the perceived impediments to acting all impact their tendency to adopt health-promoting practices. The HBM presents a theoretical framework for grasping how patients and healthcare professionals accept and engage with digital health technology for real-time monitoring and response in the context of boosting HIV disease surveillance in Abuja, Nigeria, utilising digital health innovations.

First, the HBM's perceived susceptibility component reveals how much people—including politicians and medical professionals are aware of the consequences of poor HIV surveillance. Stakeholders may be more willing to accept digital health technologies like electronic reporting and AI-driven predictive modelling if they perceive that insufficient monitoring contributes to the spread of HIV by delaying identification and care (Gillam., 1991). In a similar vein, those

who feel they are at a high risk of getting HIV would be more willing to utilise digital health platforms for care access and self-monitoring.

People's thoughts of the seriousness of HIV as a public health issue are underscored by the perceived severity component. Healthcare practitioners and governments may prioritise digital developments for real-time monitoring if they grasp the critical repercussions of delayed HIV diagnosis and the impact of poor surveillance on epidemic control. Public health professionals may respond to emerging epidemics more effectively by integrating geospatial mapping with electronic health records (EHRs), which may minimise HIV-related morbidity and mortality (Champion & Skinner, 2008).

One of the most significant reasons driving behaviour change is the perceived benefits of embracing digital health technology. Healthcare personnel are more motivated to use digital surveillance tools into routine HIV monitoring if they perceive that they boost data accuracy, optimise resource allocation, and speed up epidemic response. Additionally, persons living with HIV might be more inclined to employ mobile health (mHealth) applications if they feel that they will promote treatment adherence (Janz & Becker, 1984).

The usefulness of digital health technology, however, may be limited by the perceived impediments to adoption. Implementing digital surveillance systems effectively may be limited by concerns including insufficient infrastructure, healthcare professionals' lack of digital literacy, data security fears, and unwillingness to accept new technology (Adepoju, 2020). To optimise the benefit of digital health technologies on HIV monitoring in Abuja, these obstacles must be overcome by government financing, capacity-building initiatives, and technical improvements.

To sum up, the Health Belief Model provides a useful framework for grasping how interested parties view and respond to the use of digital health technologies in HIV monitoring. It is feasible to adapt public health approaches to promote the adoption of real-time monitoring tools by addressing perceived vulnerability, severity, benefits, and hurdles. In addition to technological advancements, behavioural initiatives that educate stakeholders of the relevance of these instruments in enhancing HIV disease monitoring are important for effectively deploying digital health technology.

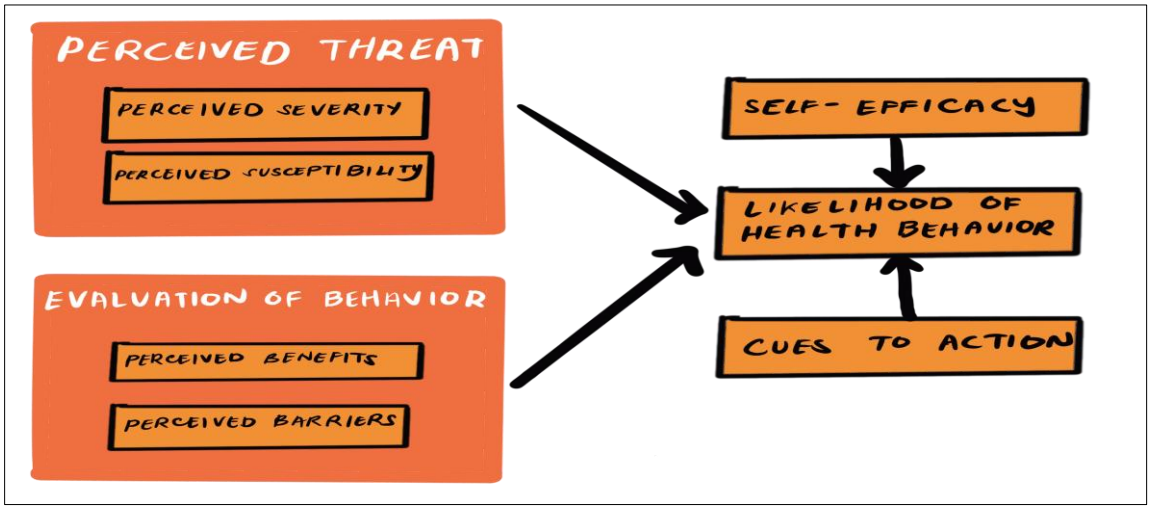

Figure 1 Depiction of the Health Belief Model. Accessed from https://thedecisionlab.com/reference-guide/psychology/health-belief-model

In Abuja, Nigeria, the Health Belief Model (HBM) offers a helpful framework for comprehending how patients and medical staff embrace and utilise digital health technology for real-time HIV disease monitoring. The Perceived Threat is crucial; patients and healthcare professionals need to understand the Perceived Severity of HIV and its effects on public health, as well as their Perceived Susceptibility to inadequate disease management or delayed diagnosis in the absence of digital monitoring. Adoption is influenced by Evaluation of Behaviour because Perceived Benefits (like better disease tracking, quicker response times, and better patient outcomes) must be greater than Perceived Barriers (like reluctance to new technology, lack of digital literacy, or data privacy concerns). While Cues to Action, including government regulations, rewards, or epidemic notifications, might encourage active involvement, Self-Efficacy, or self-assurance in using digital technologies, is essential for assuring successful engagement. According to the model, raising awareness of how serious HIV is, showcasing the advantages of digital monitoring, lowering technical hurdles, and

offering the required training would all increase the possibility of adoption and, in the end, improve HIV disease surveillance and response in Abuja.

2.8.2. Technology Acceptance Model

The Technology Acceptance Model (TAM) is a theoretical paradigm that describes how humans acquire and utilise technology, especially in organizational and healthcare contexts. Developed by Davis (1989), TAM posits that two primary factors influence technology adoption: perceived usefulness (PU) the degree to which an individual thinks that employing technological advances can boost their performance and perceived ease of use (PEOU) the degree to which they contend the technology will be effortless to use (Lala, 2014). These variables impact views about the technology, determining Behavioural intention and final uptake. In the context of enhancing HIV disease surveillance in Abuja, Nigeria, using digital health innovations, TAM gives insights on how healthcare professionals and policymakers embrace and integrate digital technologies for real-time monitoring and response.

In this research, perceived utility (PU) is critical in influencing the adoption of electronic reporting systems, geographical mapping, and AI-driven predictive analytics for HIV monitoring. If healthcare practitioners feel that these digital technologies increase the accuracy and timeliness of HIV data collecting, they are more likely to implement them. For instance, electronic health records (EHRs) may boost efficiency by eliminating paperwork and facilitating data exchange across stakeholders, making illness monitoring more efficient (Golinelli et al., 2020). Similarly, if policymakers see that AI-driven models can anticipate HIV epidemics and maximise resource allocation, they will likely favour the introduction of such technology.

Perceived ease of use (PEOU) also has a key effect in adoption. If healthcare personnel find digital surveillance technologies cumbersome or difficult to incorporate into their usual workflow, resistance to adoption may grow (Holden & Karsh, 2010). Factors such as poor training, technical challenges, and lack of experience with digital platforms may limit efficient adoption. To overcome this, specialised training programme s and user-friendly interfaces may be designed to boost the confidence of healthcare personnel in utilising digital health advances. The simpler these technologies are to use, the more likely they are to be accepted and implemented for HIV monitoring.

TAM also underlines the impact of external variables, such as organizational support, infrastructure, and government legislation, in driving technology adoption (Davis, Bagozzi, & Warshaw, 1989). In Abuja, a fundamental difficulty in adopting digital health advances is the availability of dependable internet connectivity, energy, and secure data storage systems. If these external conditions are lacking, even healthcare practitioners who perceive the benefit of digital technologies may struggle to implement them successfully. Therefore, building the digital health infrastructure and guaranteeing policy support is crucial to boosting HIV disease monitoring in Nigeria.

In conclusion, the Technology Acceptance Model offers a beneficial framework for assessing the uptake of digital health advances in HIV monitoring. By examining aspects such as perceived utility, perceived ease of use, and external influences, this research may discover approaches to promote technology acceptance among healthcare stakeholders. Encouraging the acceptance of digital surveillance techniques via capacity-building programs, infrastructural upgrades, and legislative interventions would be vital in boosting real-time HIV monitoring and response operations in Abuja, Nigeria.

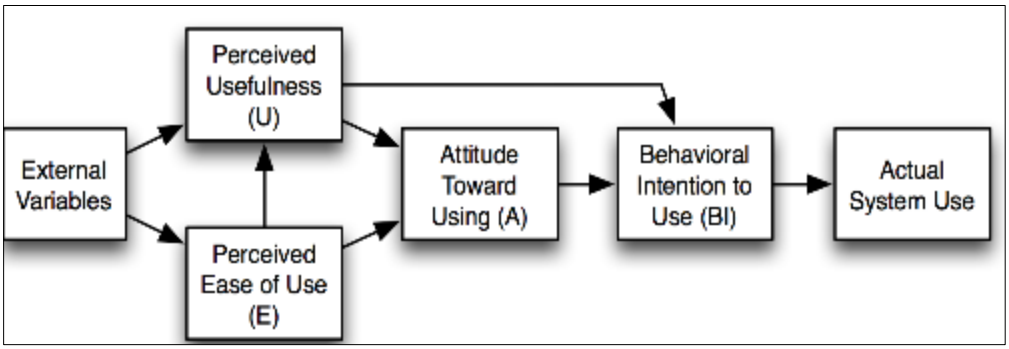

Figure 2 Graphical Display of Technology Acceptance Model. Accessed from https://en.wikipedia.org/wiki/Technology_acceptance_model#/media/File:Technology_Acceptance_Model.png

The Technology Acceptance Model (TAM) is a helpful lens through which to see how patients and healthcare providers may embrace digital health technologies for real-time monitoring and response in the context of improving HIV disease surveillance in Abuja, Nigeria. Two key views, Perceived Usefulness and Perceived Ease of Use, are influenced by external variables, including government policy, infrastructure preparedness, training, and technical assistance. Perceived utility for HIV monitoring may show up as the system's capacity to expedite patient treatment, enhance data accuracy, and provide prompt alerts all of which would improve public health outcomes in general. Perceived ease of use, on the other hand, refers to the digital system's intuitive design, seamless integration with current processes, and short learning curve all of which are essential for guaranteeing that users can effectively use the technology without incurring a substantial amount of extra labour. If the advantages are obvious and the system is easily accessible, these views then influence the users' attitude towards using the system, which promotes a positive approach. Consequently, a more positive outlook leads to a greater behavioural intention to use the technology, which in turn results in its actual use in routine HIV monitoring operations. Therefore, stakeholders may enhance the adoption and successful deployment of HIV monitoring systems in Abuja by concentrating on making the digital health tools advantageous and simple to use.

3. Materials and Methods

This study used a PRISMA-compliant systematic review approach to guarantee a well-structured and precise inquiry, making it easier to find relevant data. A thorough selection process that includes identification, screening, eligibility assessment, and final inclusion was applied to the publications that were included in this research. Several electronic databases, such as Web of Science, Scopus, IEEE Xplore, ACM Digital Library, and Google Scholar, were used to conduct an initial literature review. The search strategy used subject-specific terms together with Boolean operators to increase the range of potential articles. "HIV disease surveillance," "digital health innovations," "electronic reporting system," "geospatial mapping," and "AI-driven perspective modelling" were the main search terms used.

(1) Peer-reviewed journal articles, conference proceedings, and book chapters; (2) English-language publications; and (3) research published between 2011 and 2021 to ensure the inclusion of new information pertinent to contemporary advancements in football development were the inclusion criteria for this review. The following were the exclusion criteria: (1) research papers or publications that expressed opinions; and (2) football-focused studies that did not specifically focus on grassroots development. The first search of the bibliographic database produced 1,519 potentially relevant publications. There were 1,143 records left for screening after duplicates were removed. After reviewing the titles and abstracts, two impartial reviewers eliminated 466 articles that were deemed irrelevant and did not meet the inclusion criteria. 312 more publications were discovered in a second examination that either did not provide sufficient quality data or did not align with the study's objectives. In the end, the comprehensive systematic review had 154 sources.

Methodologically speaking, a standardised pro forma was used to gather data, documenting important details from each study such as research objectives, methodological procedures, participant details, key findings, and implications for the growth of grassroots football. Both theme synthesis and narrative synthesis techniques were used to assess the recovered material. Through the use of both qualitative and quantitative research methods, it was possible to identify recurring themes, emerging trends, and significant patterns in the literature.

The Critical Appraisal Skills Programme (CASP) checklist was used for systematic reviews, and the Mixed Methods Appraisal Tool (MMAT) was utilised for empirical articles to confirm the validity and reliability of the included research. These methods improved the final analysis's credibility and robustness by weeding out subpar research. A number of actions were taken to reduce bias and enhance the validity of the review process, such as using Cohen's κ coefficient to calculate inter-rater agreement, involving two independent reviewers in the screening and eligibility assessment, and performing searches across multiple databases to reduce publication bias. When there was disagreement, discussions were held until an agreement was reached, and a third reviewer was called if necessary to resolve disputes.

3.1. Current Challenges in HIV Surveillance in Nigeria

HIV surveillance in Abuja, Nigeria, has numerous important problems that prevent efficient monitoring and management of the pandemic. One significant concern is the low financing allotted to HIV programmes, which inhibits the installation of comprehensive monitoring systems (Edun, 2021). This financial limitation affects the ability to perform broad testing, data collecting, and analysis, important components for understanding and reacting to the epidemic’s dynamics. A study of Nigeria’s HIV control system indicates that despite advances, issues such as limited finance continue, hurting the overall efficacy of HIV monitoring operations.

Another important difficulty is the restricted availability to preventive and treatment services, especially among crucial groups such as female sex workers, men who have sex with males, and individuals who inject drugs (Umar, 2021). Stigma, prejudice, and criminalization of these groups' Behaviours add to their marginalisation, making them less likely to seek testing or disclose correct information during surveillance efforts. This underreporting leads to gaps in data, hampering the development of targeted treatments (Balogun, 2017). Research on HIV prevalence across important demographics in Nigeria underlines the need for concerted preventative methods to contain the rising pandemic among these groups.

The regional inequalities in HIV incidence within Abuja further complicate monitoring efforts. Certain places indicate greater rates of infection, needing customised data to guide focused actions (Ibekwe, 2019). However, the present monitoring systems typically lack the granularity necessary to detect and react to these localised epidemics efficiently. Fletcher-Lartey and Caprarelli (2016) noted that employing geographical information system technology has proved its effectiveness in finding locations to prioritise for HIV control among critical populations, emphasising a need for more sophisticated data gathering approaches.

Additionally, the dynamic nature of critical populations, typified by high mobility and changing Behaviours, offers a difficulty to keeping accurate and up-to-date surveillance data (Ibekwe, 2019). Traditional data gathering techniques may not catch these shifts rapidly, resulting to obsolete or missing information (Zhan et al., 2016). Innovative techniques, such as the use of capture-recapture methodologies, have been applied to estimate the sizes of important populations in Nigeria, attempting to enhance the quality of data for programme planning.

Lastly, the lack of integration and coordination among many stakeholders participating in HIV monitoring leads to fragmented data systems (Watt et al., 2017). This fragmentation leads in inconsistencies and redundancies, hindering the capacity to create a coherent knowledge of the epidemic's tendencies (Shlomo Agon, 2021). Efforts to enhance monitoring systems must concentrate on strengthening coordination among government departments, foreign partners, and civil society groups to build a united and effective response to the HIV pandemic in Abuja.

Addressing these difficulties involves a holistic strategy that includes raising financing, enhancing access to services for critical groups, utilising modern data gathering technology, and promoting cooperation among stakeholders. By addressing these challenges, Abuja may increase its HIV monitoring capacities, leading to more effective interventions and better health outcomes for its population.

3.2. Effectiveness of Digital Health Innovations in HIV Surveillance

Digital health advances have dramatically boosted HIV monitoring by enhancing data collection, processing, and distribution, leading to more effective public health interventions. The integration of electronic health records, mobile health apps, and data analytics platforms has eased the monitoring of HIV trends and permitted prompt interventions (Ndlovu et al., 2021). These digital innovations have altered conventional surveillance approaches by assuring real-time reporting, boosting accuracy, and enabling evidence-based decision-making in public health systems.

One major improvement is the use of digital sites for real-time data collecting and reporting. These technologies allow healthcare professionals to immediately submit case information, decreasing delays associated with conventional reporting techniques. By eliminating reporting gaps, digital systems enable for speedier responses to outbreaks and improved monitoring of HIV trends. For example, the District Health Information Software 2 (DHIS2) is an open-source platform extensively used in over 75 low- and middle-income countries for health data administration, including HIV monitoring. Its deployment has resulted to enhanced data accuracy, easy access to health data, and more effective coordination of actions, ultimately enhancing public health systems (Green et al., 2020).

Mobile health (mHealth) strategies have also played a vital role in HIV monitoring. The widespread usage of mobile phones enables for effective data gathering and contact with patients, especially in distant places where access to healthcare services is restricted (Al-Arkee et al., 2021). Mobile health apps enhance the monitoring of treatment adherence, give automatic reminders for medication, and allow communication between healthcare practitioners and patients (Tabi et al., 2019). Digital health technologies are being leveraged for HIV prevention and treatment, utilising the high prevalence of mobile devices across diverse demographic groups (Mikulski et al., 2021). The accessibility of mobile health solutions helps bridge gaps in healthcare delivery, enhancing engagement and health outcomes for those living with HIV.

Furthermore, digital health advances offer real-time Behaviour monitoring of important groups including persons living with HIV/AIDS (PLWHA). Since people commonly utilise digital platforms for communication, these platforms may

improve HIV monitoring by offering insights into Behaviours and trends among target groups (Tabi et al., 2019). Social media analytics, AI-driven prediction modelling and geographic mapping assist identify high-risk populations and analyse the success of intervention methods (Green et al., 2020). By examining digital footprints and Behavioural patterns, public health professionals may modify HIV prevention programme s, customise instructional efforts, and enhance service delivery to the most susceptible groups.

In summary, digital health technologies have proved helpful in strengthening HIV monitoring by allowing real-time data collecting, promoting patient involvement, and offering insights into crucial groups. These developments help to more responsive and focused public health interventions, eventually assisting in the control and prevention of HIV. As technology continues to improve, incorporating digital health solutions into HIV monitoring systems will be vital for attaining long-term public health objectives and lowering the worldwide burden of HIV/AIDS.

3.3. Challenges in Implementing Digital Health Innovations in Abuja, Nigeria

Implementing digital health innovations in Abuja, Nigeria, offers various hurdles that prevent the proper integration of technology into the healthcare system. One key hurdle is the poor infrastructure, notably unpredictable electrical supply and limited internet access (Ifeoluwa, 2016). These flaws restrict the consistent functioning of digital health solutions, making it difficult for healthcare practitioners to depend on technology for patient care and data administration. noted that such infrastructure difficulties adversely impair healthcare delivery in Nigeria, stressing the need for considerable upgrades to support digital health efforts.

Another important problem is the lack of digital literacy among healthcare personnel and patients. Many healthcare practitioners in Abuja may not possess the essential skills to successfully apply digital health tools, resulting to underutilization or inappropriate implementation of these technology. Similarly, patients' unfamiliarity with digital platforms might result in poor engagement, consequently limiting the potential advantages of digital health treatments. Research reveals that digital illiteracy is a key impediment to the effective deployment of mobile health advances throughout Africa, especially Nigeria.

Financial restrictions can represent a considerable obstacle. The enormous costs involved with obtaining, installing, and sustaining digital health systems might be prohibitive, particularly in resource-limited environments like Abuja. Limited financing may lead to fragmented and unsustainable digital health projects, since there may not be sufficient resources to enable long-term operation and growth of these technologies. A analysis analysing the influence of digital transformation on healthcare delivery in Nigeria highlighted budgetary limits as a critical hurdle to the broad adoption of digital health technologies.

Furthermore, worries surrounding data security and privacy are prominent. The worry over the confidentiality of personal health information might lead to reluctance from both healthcare practitioners and patients in embracing digital health solutions. Ensuring adequate data security measures is vital to develop confidence and promote the usage of digital platforms in healthcare settings. Studies have shown that resolving data security concerns is vital for the effective adoption of digital health treatments in Nigeria.

In conclusion, although digital health technologies offer potential for enhancing healthcare delivery in Abuja, Nigeria, addressing obstacles related to infrastructure, digital literacy, budgetary restrictions, and data security is crucial for effective adoption. Comprehensive plans that incorporate investment in infrastructure, capacity training, sustainable finance, and comprehensive data security procedures are important to overcome these challenges and fully exploit the advantages of digital health technology.

3.4. Proposed Strategies for Strengthening HIV Surveillance in Abuja

Strengthening HIV monitoring in Abuja, Nigeria, is critical for successful public health interventions and reaching the aim of ending the HIV epidemic by 2030. To strengthen surveillance efforts, numerous solutions might be proposed:

- **Enhancing Data gathering and Management Systems:** Implementing strong electronic health information systems may increase the quality and timeliness of HIV data gathering. The use of platforms like the District Health Information Software 2 (DHIS2), an open-source technology extensively used in low- and middle-income countries, may allow real-time data reporting and analysis. This approach allows healthcare practitioners to immediately submit case information, eliminating delays associated with conventional reporting techniques and boosting the ability for fast public health interventions.
- **Integrating Mobile Health (mHealth) Technologies:** Leveraging the extensive usage of mobile phones in Abuja may promote effective data gathering and contact with patients. Mobile health apps may enable the

monitoring of treatment adherence, give automatic reminders for medication, and simplify communication between healthcare practitioners and patients. Digital health technologies are being leveraged for HIV prevention and treatment, utilising the high prevalence of mobile devices across diverse demographic groups.

- **Building Capacity Among Healthcare Workers:** Training healthcare workers in the use of digital health technologies is vital for efficient HIV monitoring. Capacity-building programme s should concentrate on boosting digital literacy, data management skills, and the capacity to comprehend and use surveillance data for decision-making.
- **Strengthening Community Engagement:** Engaging local communities in surveillance activities may increase data accuracy and promote confidence between healthcare practitioners and the public. Community-based monitoring programs may motivate people to report instances, adhere to treatment, and engage in preventative programme s. A concentrated preventative strategy is required to manage the increasing pandemic among critical groups that comprise the epicentre of the HIV epidemic in Nigeria.
- **Ensuring Data Security and Privacy**: Addressing concerns surrounding data security and privacy is vital to develop confidence and promote the usage of digital platforms in healthcare settings. Implementing comprehensive data security mechanisms and educating stakeholders about data privacy helps alleviate reluctance from both healthcare professionals and patients in implementing digital health solutions.
- **Securing Sustainable financing:** Establishing sustainable financing channels is crucial for the long-term effectiveness of HIV monitoring projects. Collaborations with government agencies, foreign partners, and civil society groups may mobilize resources to assist the procurement, installation, and maintenance of digital health systems. An analysis analysing the influence of digital transformation on healthcare delivery in Nigeria highlighted budgetary limits as a critical hurdle to the broad adoption of digital health technologies.

By following these techniques, Abuja may enhance its HIV monitoring system, leading to more responsive and focused public health interventions. These measures are crucial to manage and prevent HIV efficiently within the community.

3.5. Proposed Strategies HIV Disease in Abuja by Leveraging Digital Health Innovations

Strengthening HIV disease monitoring in Abuja by using digital health technologies needs a comprehensive strategy that incorporates technology, capacity training, and policy assistance. Digital health technologies may boost data collecting, real-time monitoring, and intervention tactics, eventually enhancing public health responses. Below are some techniques to strengthen HIV surveillance utilising digital health technology.

- One key approach is the growth and integration of electronic health information systems (EHIS). Implementing strong digital reporting systems such as the District Health Information Software 2 (DHIS2) and Electronic Medical Records (EMRs) may boost data accuracy and allow real-time reporting. These systems enable healthcare practitioners to capture, analyse, and analyse HIV-related data, guaranteeing quick decision-making and action. Studies have demonstrated that incorporating EHIS into health systems considerably minimises data loss and enhances disease monitoring efficiency (WHO, 2022).
- Another successful technique is employing mobile health (mHealth) technology for data gathering and patient involvement. Mobile apps, SMS-based reporting, and telemedicine platforms may facilitate communication between healthcare clinicians and people living with HIV/AIDS (PLWHA). These devices may be used for adherence tracking, appointment reminders, and health education. In places like South Africa and Kenya, mHealth interventions have increased treatment retention and viral load reduction (Dovel et al., 2020). Adopting comparable tactics in Abuja may overcome healthcare gaps and guarantee more complete monitoring.
- Geospatial mapping and artificial intelligence (AI)-driven predictive modelling are also vital for enhancing HIV monitoring. Geospatial mapping, using Geographic Information Systems (GIS), helps depict disease patterns, identify high-risk locations, and allocate resources effectively. AI-powered prediction algorithms can scan vast datasets to detect growing hotspots and anticipate prospective epidemics, enabling preventive actions. Research demonstrates that incorporating AI in HIV monitoring might increase early detection and epidemic management efforts (Scarpino & Petri, 2019).
- Capacity development among healthcare staff is another crucial technique. Digital literacy training programmes should be created to educate healthcare personnel with the required abilities to utilise digital health products successfully. Training should concentrate on data administration, electronic reporting systems, and AI-based decision-making tools. Strengthening the technical skills of healthcare personnel will increase data quality and usage in HIV monitoring initiatives.
- Finally, guaranteeing data security and policy support is crucial to the effective adoption of digital health advances. Given concerns regarding data privacy, rigorous cybersecurity measures should be established to secure patient information. Policymakers should design and implement policies that support the ethical use of digital health technology while guaranteeing compliance with global data protection standards. Additionally,

consistent financing from government agencies and foreign partners is important to support the scalability and sustainability of digital health programs in Abuja.

By employing these measures, Abuja may greatly strengthen HIV disease surveillance, resulting to enhanced disease monitoring, better patient outcomes, and more effective public health interventions. Digital health advances provide a radical approach to addressing HIV, guaranteeing that healthcare practitioners can react more effectively and proactively to the pandemic.

4. Conclusion and Recommendations

HIV disease monitoring in Abuja has substantial problems because to constraints in conventional reporting methods, data management inefficiencies, and delayed responses to rising health hazards. The combination of digital health innovations such as electronic reporting systems, GIS mapping, and AI-driven predictive modelling offers transformational possibilities for enhancing surveillance accuracy, timeliness, and overall public health outcomes. These advances promote real-time data collecting, enabling early identification of epidemics, and boost the efficiency of resource allocation for HIV prevention and treatment. However, problems such as digital infrastructure inadequacies, data security concerns, and inadequate technical skill among healthcare professionals must be addressed to optimise the effect of these technologies.

4.1. Policy and Practical Implications for HIV Surveillance in Abuja

Policymakers should emphasise the adoption and integration of digital health technologies into the current healthcare system by adopting supporting policies and frameworks. First, there should be a requirement for the countrywide adoption of electronic health records (EHRs) and interoperability amongst health information systems to facilitate smooth data sharing. Second, investments in digital infrastructure, such as dependable internet access and cloud-based data storage, are essential to enable electronic surveillance programs. Third, clear data governance regulations must be created to preserve patient privacy while ensuring that surveillance data is available to permitted public health stakeholders. Fourth, training programme s should be undertaken to enhance the capability of healthcare personnel in utilising digital health technologies efficiently. Finally, collaborations with private-sector technology businesses and international health organizations may allow sustainable finance and technical knowledge for digital health projects in HIV monitoring.

4.2. Future Research Directions on Digital Health Innovations in Disease Surveillance

Further study is required to evaluate the long-term influence of digital health technologies on disease surveillance results. One crucial issue is the usefulness of AI-driven predictive models in improving epidemic forecasts and targeted response tactics. Future research should examine the accuracy and dependability of these models in real-world public health contexts. Another area of study is the importance of big data analytics in HIV surveillance, specifically how incorporating socioeconomic determinants of health (e.g., poverty levels, movement patterns, and stigma-related hurdles) might improve data-driven decision-making. Additionally, research should evaluate the scalability and sustainability of digital health treatments in low-resource contexts, focusing on cost-effectiveness and infrastructure needs. Lastly, research on community involvement and digital health literacy may give insights into how mobile health (mHealth) apps can be successfully leveraged to improve HIV prevention and treatment adherence among critical groups.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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