Socio-demographic Factors Influencing the Adoption of Digital Health Tools for Public Health Emergencies in Northern Nigeria

Maureen O. Anyanwu
School of Public Health, Texila American University, Georgetown, Guyana, South America

Abstract

This study assessed the determinants influencing the adoption of digital health tools for public health emergencies in primary healthcare centres in Nigeria. The research was conducted in registered primary healthcare centres located in Abuja-Federal Capital Territory, Niger, and Nasarawa in Northcentral Nigeria. A multistage sampling technique was employed, utilizing pretested semi-structured questionnaire for data collection. The findings revealed the recent implementation of 11 digital health tools. The tools were classified into categories: Disease Surveillance and Response Systems, Data Collection, Analytics, Visualization and Use, and Logistics and Supply Chain Management. Key factors affecting the adoption of these tools included Age ($\chi^2 = 203.64$, $p < 0.001$), Sex ($\chi^2 = 136.92$, $p < 0.001$), Marital Status ($\chi^2 = 44.64$, $p < 0.001$), Level of Education ($\chi^2 = 8.37$, $p = 0.007$), Rate of IT Knowledge ($\chi^2 = 228.22$, $p < 0.001$), Profession ($\chi^2 = 151.55$, $p < 0.001$), and PHC ($\chi^2 = 212.79$, $p < 0.001$). The findings indicate that multiple demographic and professional factors significantly influence the adoption of digital health tools. The research identified key factors that affect the effective implementation and adoption of these technologies. Identified key enablers comprise robust infrastructure, stakeholder engagement, policy development, financial sustainability, and user-centred design. By addressing these barriers and leveraging identified enablers, Nigeria can improve its preparedness and response to public health emergencies, thereby enhancing healthcare outcomes and greater equity in health services. This study offered insights and recommendations for policymakers and practitioners focused on advancing sustainable digital health initiatives Nigeria.

Keywords: *Digital Health, Nigeria, Primary Healthcare Centres, Public Health Emergencies.*

Introduction

It is essential to prioritize the integration of digital health into community and primary healthcare initiatives in order to improve and monitor access to outstanding and equitable health services [1]. The primary healthcare infrastructure in Nigeria is unstable, which poses a substantial challenge to the Nigerian healthcare system, according to the 2019 report released by the Federal Government of Nigeria [2]. The inadequacies in the robustness and resilience of health systems were exposed by the COVID-19 pandemic, according to [3]. They were certain that multi-dimensional initiatives to strengthen health systems will be essential for achieving the necessary preparedness and agility to address future public health crises.

The healthcare sector is becoming more reliant on information. At present, the provision of healthcare necessitates the implementation of information-intensive business processes. In order to improve population health through evidence-based decision-making, healthcare administrators are increasingly relying on real-time information exchange that is derived from high-quality, easily accessible data.

The implementation of digital health technologies can facilitate, sustain, and accelerate progress in universal health coverage (UHC) [4]. The alignment of catalytic mechanisms to facilitate the dissemination and gradual adoption of digital health technologies, with the integration of information and communication technologies (ICTs) and enhanced organizational capacity, supported by appropriate systems, structures, and resources, has proven essential for fostering rational and effective decision-making. This is in addition to the implementation of efficient people-centered management practices that aim to improve information flow [5]. Health systems must consistently adapt and modify themselves to align with local circumstances, ensuring a coordinated response to the requirements and expectations of the population, despite the fact that the implementation of health services should vary by context.

It is imperative to capitalize on the impetus of evolving health concerns, requirements, and expectations in order to expedite the adoption of innovative technology. Investing in and promoting synergy, alleviating restrictive obstacles, enhancing interoperability, and developing user-friendly platforms to expedite coordination, communication, and decision-making are all ways to achieve this.

Data is essential for informing policy, strategic, and evidence-based decision-making, monitoring provider performance and implementing regulatory measures, and creating evidence-informed tools for the high-quality and consistent delivery of services [6].

Technology improves efficiencies in clinical and public health. It significantly enhances disease prevention, surveillance, case identification, investigation, and follow-up without causing significant disruptions to the standard workflow [7]. And this can be accomplished without the introduction of any additional significant challenges.

The utilization of digital health tools is becoming increasingly important in the administration of public health emergencies, particularly in primary healthcare centers in low- and middle-income countries (LMICs) like Nigeria.

Digital health tools encompass a variety of technologies that are designed to enhance the delivery and management of health services. These tools are indispensable for optimizing the timeliness, precision, and efficiency of health data collection, disease surveillance, and response initiatives. In the event of public health emergencies, such as infectious disease outbreaks, these tools are indispensable for facilitating the rapid and efficient response by healthcare professionals. The rapid detection, notification, and response to public health risks/emergencies are essential components of surveillance, which is a core competency in International Health Regulation (IHR). Consequently, a surveillance system that is both sensitive and adaptable is required, as well as an early warning function, to monitor epidemics and detect changes in epidemiological data in a timely manner to enable effective action [8].

A disease surveillance system must be adaptable enough to accommodate the changing requirements of public health systems. This includes the automation of data collection and real-time task processing, the integration of robust data analytics and connected visualizations, and the linking of surveillance systems between siloed systems to facilitate communication and actionable information sharing with public health partners across organizational boundaries. Nevertheless, digital technologies offer the potential to improve the delivery of a diverse array of health services, increase the responsiveness of health systems to the needs of individuals and communities, and improve the accessibility of health services [6].

In Nigeria, primary healthcare centers (PHCs) are the primary point of contact for individuals seeking health care, thereby playing a critical role in the early detection and

management of public health emergencies. There are numerous challenges associated with the implementation of digital health tools in these contexts. It is essential to examine the factors that influence the adoption of these tools in order to develop strategies that will effectively overcome obstacles and encourage their sustainable adoption. PHCs serve as the frontline in the healthcare delivery system in Nigeria, providing essential services to vast populations, particularly in rural and underserved areas. In these settings, the timely adoption of digital health tools can greatly improve disease surveillance, data collection, health information management, and logistics. However, several determinants influence the implementation and sustainable adoption of these tools, and understanding these factors is crucial for developing effective strategies to address barriers and leverage enablers.

Primary healthcare professionals expressed their apprehensions regarding the lack of sufficient involvement in the planning process, the absence of a contextual and comprehensive national policy and plans for e-health, and the downsizing of implementation at the local level, which is also contingent upon the active participation of all stakeholders in the planning and implementation process [9]. Hence, the determinants that influence the use and sustainable adoption of digital health tools for public health emergencies in PHCs in Nigeria were the focus of our study.

This research underscores the significance of a variety of demographic and professional factors, such as age, sex, marital status, education level, IT knowledge, and profession, in influencing the adoption of digital health tools. This study also investigated determinants to provide a deeper understanding of the enablers and barriers that influence the adoption of digital health tools in PHCs in Northern Nigeria. The results will offer policymakers, healthcare providers, and other stakeholders, practicable strategies on how to effectively promote and sustain the adoption of digital

health technologies for public health emergencies within the scope of the study.

One of the objectives of this research is aimed at assessing the implementation of the digital health tools adopted for public health emergencies; of course, towards enhancing healthcare outcomes and promote equity in health services in Nigeria and other LMICs.

Nigeria encounters recurrent natural and environmental calamities, alongside violent conflicts such as insurgency and sectarian strife. Nigeria's public health concerns are escalating due to fast population growth, increased mobility, infrastructure degradation, and outbreaks of infections, especially in Northern Nigeria. The governments of Liberia, Guinea, and Sierra Leone demonstrated a delayed response in implementing necessary emergency measures and maintaining a consistent communication strategy during the Ebola outbreaks in West Africa, which hindered the effective containment of the outbreak [10]. Nigeria's public health system has experienced a significant rise in cases and fatalities since January 2024 [11], as a result of cholera outbreaks that have been reported in more than 35 states. During any emergency situation, data is gathered that possesses the potential to guide actions and enhance the quality, efficiency, or impact of the response [12]. This may encompass activities such as identifying and prioritizing gaps and needs, mobilizing existing resources and efforts, coordinating response initiatives to prevent redundant efforts, advocating for the allocation of resources, or monitoring interventions [12]. Surveillance data, like survey data, are predominantly quantitative and collected using standardized tools and forms. This can be accomplished through the use of active methods, such as soliciting information from communities. Alternatively, employing passive methodologies, such as meticulously documenting every case presented at the health center [13].

Digital health is a dynamic domain within the health sector that has the potential to aid in achieving health objectives by providing timely, accurate, and comprehensive health information to inform decision-making and service provision. In light of the imperative to integrate emerging domains such as artificial intelligence, big data, and genomics, as well as the application of advanced computing sciences, the phrase "digital health" is becoming increasingly prevalent [14].

Health 4.0, which is derived from the principles of Industry 4.0, is a transformation in the healthcare industry's business model. It is designed to improve interactions among healthcare clients (patients), infrastructure, and various stakeholders, as stated by [15]. It emphasizes the importance of innovative technologies in the provision of cost-effective, value-added, and improved healthcare services, as well as in the delivery of healthcare. These technologies were defined as resources management applications, patient-centered applications, tools for healthcare professionals, systems for epidemic and pandemic preparedness, and advanced healthcare systems management applications [16].

Every country faces a significant social and economic challenge regarding healthcare. Currently, healthcare administrators, clinicians, researchers, and other practitioners in the field are under increasing pressure due to escalating public and private expectations [17]. The escalating costs of healthcare have significant effects on the quality of life of individuals. Concurrently, the persistent increase in population has a substantial impact on the demand for healthcare, necessitating the development of novel and more complex scientific interventions [18]. Although, the advancements in ICTs have significantly contributed to the development and enhancement of healthcare solutions in recent times, the deployment of digital health in Africa has several challenges, including poor coordination of pilot projects, deteriorating healthcare systems, lack of awareness and comprehension, inadequate infrastructure, and non-interoperability issues [19], [20], [21].

It is evident that Africa is currently grappling with fragmented digital health deployment endeavours. But this perceived missing link is yet to be fully explored through necessary empirical research in Nigeria to date. Despite their potential benefits, the uptake and sustainable integration of digital health tools in Nigerian primary healthcare centres remain fraught with challenges. Therefore, this study was designed to examine the factors that influences adoption of digital health tool in primary healthcare centres in Nigeria. It is this gap in research that this study intends to fill to extend the frontiers of knowledge in digital healthcare management.

Furthermore, there is insufficient information regarding the factors that influence the sustainable adoption of digital health tools in primary healthcare settings, particularly in Northern Nigeria, where they are intended to be used by healthcare professionals. Consequently, the objective of this research is to investigate the variables that affect the sustainable adoption and utilization of digital health instruments in PHCs in Nigeria. This research focused on a comprehensive range of factors, including demographic characteristics (such as age, sex, and marital status), educational levels, IT knowledge, and professional backgrounds of the healthcare workers. In addition, it examines the technical and infrastructural elements that facilitate or hinder the integration of digital health solutions.

The problem is further compounded by the diverse and complex healthcare landscape in Nigeria, where disparities in infrastructure, resource allocation, and policy implementation pose significant challenges. In the face of these obstacles, there is an urgent need for targeted research to identify and address the specific determinants that impact the adoption of digital health tools in Nigerian PHCs.

By providing a contextual analysis of these factors, this study aims to inform policymakers, healthcare providers, and other stakeholders on the critical areas that require attention to enhance the effective use adoption of digital health technologies.

The ultimate goal is to improve the readiness and capacity of primary healthcare centres in Nigeria to manage public health emergencies, thereby contributing to better health outcomes and increased resilience in the healthcare system.

Methodology

Study Design

This study utilized a cross-sectional facility-based design.

Study Area

This study was undertaken in three states of the Northern region: Nasarawa, Niger, and FCT-Abuja.

Study Population

The study population included doctors/nurses, disease surveillance and notification officers (DSNOs), local government area monitoring and evaluation officers (M&EOs), record officers, community health extension workers (CHEWs), and community health workers (CHWs) from the State Primary Healthcare Development Agency of the respective states.

Inclusion Criteria

Recruitment for the study was limited to healthcare professionals within the jurisdiction of the SPHCDA (State, LGA and HF levels) who are 18 years and above and have given their consent to participate.

Exclusion Criteria

Non-healthcare professionals and healthcare workers who have not given their consent were excluded from the study.

Sample Size Determination

The sample size for the quantitative sample was calculated using the standard formula for estimating a single population proportion:

$$n = \frac{\left(Z_{1-\frac{\alpha}{2}}\right)^2 P(1-P)}{d^2}$$

$Z_{1-\frac{\alpha}{2}}$= Standard normal variate (at 5% type 1 error ($\check{P}$<0.05) is 1.96)

P = Expected proportion in population based on previous studies implementing digital health=27.3% [22]

d = Absolute error or precision=0.05

$$n = \frac{(1.96)^2 0.273 \times (0.727)}{0.05^2} = 305$$

$$n = 113 \; per \; group$$

Non-response rate: Individuals may decline to participate while they have been selected through random methods.

By accounting for a 10% non-response rate:

Final sample size=Effective sample size/1-NR anticipated

$$n = \frac{305}{0.9} = 339$$

Sampling Technique

The multi-stage sampling technique was carried out in this investigation. The first stage entailed the purposive selection of one geopolitical zone (Northcentral) from the six geopolitical zones in Nigeria, with a focus on the level of security hazards, particularly armed insurgency. From the seven (7) states in the Northcentral geopolitical zone, three (3) were selected through a simple random sampling process by balloting: Abuja, Niger, and Nasarawa.

In the third stage, balloting is employed to identify two (2) LGAs per senatorial district in each of the selected states that have the highest number of accessible PHCs and have implemented digital health tools for public health emergencies. The fourth stage involved purposive sampling method to identify accessible primary healthcare centers where digital health tools have been implemented within the chosen local government areas. The

study's recruitment focused exclusively on healthcare professionals working under the State Primary Health Care Development Agency's jurisdiction, who are 18 years or older and have provided their consent to participate.

Data Collection Methods

Research assistants were recruited from each state and received training on the data collection instrument after the questionnaire was translated into ODK (Open Data Kit), a user-friendly application for data collection designed for the Android operating system. The pre-tested semi-structured questionnaire was administered among healthcare professionals who actively engaged in the implementation of digital health tools.

Validation of Questionnaire

The reliability of the instrument was assessed by using a subset of the sample size, specifically 10%, and the questionnaire was distributed to a population comparable to the sample population in a different State. Necessary modifications were done following the pre-test.

The validation of the digital health survey instrument was conducted through the application of Cronbach's alpha. The Cronbach alpha value range of the e-value scale indicated a satisfactory validation estimate of 0.93. Furthermore, the Cronbach alpha value remained within a similar range when an item was deleted.

Data Management and Analysis

To increase accuracy, data was entered, refined, and encoded. Our evaluation assessed their comprehensiveness and reliability. Next, the questionnaire was carefully inspected for errors, coded, and entered into SPSS version 25.0. Descriptive and inferential statistics were used. For bivariate analysis, Chi-square was used. Structural equation Modeling (SEM), a multivariate technique, was used to estimate and test complex correlations between dependent and independent variables and show how they interact.

For this investigation, a p-value of less than 0.05 indicated 95% confidence.

Ethical Considerations

Ethical clearance was secured from the National Health Research Ethics Committee of Nigeria (NHREC), with the approval number NHREC/01/01/2007-28/06/2024. The study participants provided informed verbal and written consent prior to completing the questionnaire, following an explanation of the study's objectives and significance. The collected data was maintained in a confidential manner. The questionnaire was composed in English, the language comprehended by the participants in the study area. All data collected for this study underwent coding, and no names or identities would be utilized in any publications or reports.

Results

The characteristics of the participants recruited for this study from the selected PHCs in the three states are presented in Table 1. The majority of participants, 105 (34.0%), were between the ages of 31 and 40. And the majority of health practitioners, 195 (63.1%), were male. Furthermore, a substantial proportion of the participants were married, with 243 (78.6%), and 305 (98.7%) having completed at least tertiary education, respectively. In addition, 109 individuals (35.3%) exhibited a minimum level of IT knowledge. The plurality of PHCs, 168 (54.4%), were situated in rural areas and utilized at least one digital health tool.

Table 1. Descriptive Statistics of the Respondents' Characteristics

Variable	Frequency	Percentage
Age		
21-30	57	18.4

31 – 40	105	34.0
41 – 50	101	32.7
51 Above	46	14.9
Sex		
Male	195	63.1
Female	114	36.9
Marital Status		
Single	63	20.4
Married	243	78.6
Separated/Divorced	3	1.0
Level of Education		
Primary/secondary	4	1.3
Tertiary	305	98.7
Rate of IT Knowledge		
Fairly	109	35.3
Minimum	120	38.8
Maximum	77	24.9
None	3	1.0
Profession		
Doctor/Nurse	90	29.1
CHEW/DSNO	82	26.5
Record officers	137	44.3
PHC location		
Rural	168	54.4
Semi-Urban	88	28.5
Urban	53	17.2
Digital Health Tools		
SORMAS	9	2.9
ODK	77	24.9
DHIS2	21	6.8
eIDSR	2	0.6
EMID	1	0.3
LoMIS	8	2.6
RI SMS	2	0.6
NIPDS	29	9.4
E-HEALTH CARD	34	11.0
Survey CTO	56	18.1
OpenLMIS	70	22.7

Descriptive Statistics of Digital Health Tools

The questionnaire was utilized to assess participants' perceptions regarding the usefulness, ease of use, relative advantages, awareness, risks, data security, infrastructure, critical success factors, staff experience, information sharing, and the technical

infrastructure related to the adoption of digital health tools.

In the subscale evaluating the perceived usefulness of the digital health tool, around 150 respondents (48.5%) agreed that these tools improve their task completion capabilities, while 202 respondents (65.4%) recognized that digital health tools streamline their work processes or simplify their tasks. Regarding ease of use, the subscale indicated that 79 (25.6%) participants experienced general frustration with digital health tools/systems, whereas 228 (73.8%) stated that they found these tools/systems easy to use. The majority of participants indicated access to the available digital health tools, with 214 (69.3%), and 203 (65.7%) expressing an understanding of the benefits associated with their use. A considerable portion of participants, 88 (28.5%), indicated an inconsistency in electricity supply, whereas 71 (23.0%) voiced their discontent with the quality of the network at their facility. The subscale evaluating critical success showed that 244 individuals (79.0%) reported that the use of digital health tools enhances their control over their work, while 223 individuals (72.2%) indicated that these tools improve the quality of their work. In the information sharing subscale, 102 (33.0%) reported that digital health tools/systems improve information sharing within the health facility, whereas 154 (49.8%) indicated that these tools/systems facilitate information sharing with other health facilities. A significant portion, 192 (62.1%), agreed that an overemphasis on safeguarding patients' privacy affects the use of digital health tools and systems. The technical infrastructure subscale revealed that 216 (69.9%) and 244 (79.0%) participants concurred that the IT budget of the health facility is adequate to maintain and support the digital health tools/system; and that the current infrastructure of the health facility is sufficient to support the digital health tools/system, respectively.

Available Digital Health Tools for Public Health Emergencies in Primary Healthcare Settings Across the Three States

We assessed the diverse digital health tools that have been implemented in the PHCs for public health emergencies over the past five years. Overall, approximately 11 digital health instruments have been implemented during this period. The primary tool employed during this timeframe was ODK 77 (24.9%), followed by OpenLMIS 70 (22.7%), survey CTO 56 (18.1%), E-health card 34 (11.0%), NIPDS 29 (9.4%), SORMAS 9 (2.9%). However, RI SMS was the least utilized instrument, with a usage rate of only 0.6%.

Categories of Assessed Digital Health Tools

Table 2. The Three Groups of the Assessed Digital Health Tools

	Frequency	Percentage
Digital Health Tools		
Logistics & Supply Chain Management	80	25.9
Disease Surveillance & Response Systems	41	13.3
Data Collection, Analytics, Visualization & Use	188	60.8

Disease Surveillance & Response Systems: SORMAS, eIDSR, NIPDS

Data Collection, Analytics, Visualization & Use: ODK, DHIS2, SurveyCTO, E-health Card, EMID

Logistics & Supply Chain Management: LoMIS, RI SMS, OpenLMIS

A national case study conducted by the Federal Ministry of Health in 2022 reported that a number of these tools were collected as part

of the digital health tools for pandemic preparedness in Nigeria.

Socio-demographic Factors that Influences the Adoption of Digital Health Tools

Table 3. Assessing the Relationship between Responses from the Digital Health Survey and Digital Health Tools

Variable	Logistics & Supply Chain Management n (%)	Disease Surveillance & Response Systems n (%)	Data Collection & Health Information Management n (%)	Chi-square	p-value
Age					
21-30	0 (0.0)	9 (22.0)	48 (25.5)	203.64	<0.001
31 – 40	10 (12.5)	32 (78.0)	63 (33.5)		
41 – 50	24 (30.0)	0 (0.0)	77 (41.0)		
51 Above	46 (57.5)	0 (0.0)	0 (0.0)		
Sex					
Male	10 (12.5)	41 (100.0)	144 (76.6)	136.92	<0.001
Female	70 (87.5)	0 (0.0)	44 (23.4)		
Marital Status					
Single	0 (0.0)	9 (22.0)	54 (27.7)	44.64	<0.001
Married	77 (96.3)	32 (78.0)	134 (71.3)		
Separated/Divorced	3 (3.8)	0 (0.0)	0 (0.0)		
Level Education					
Primary/secondary	4 (5.0)	0 (0.0)	0 (0.0)	8.37	0.007
Tertiary	76 (95.0)	41 (100.0)	188 (100.0)		
Rate of IT Knowledge					
None	3 (3.8)	0 (0.0)	0 (0.0)	228.22	<0.001
Fairly	0 (0.0)	11 (26.8)	98 (52.1)		
Minimum	10 (12.5)	30 (73.2)	80 (42.6)		
Maximum	67 (83.8)	0 (0.0)	10 (5.3)		
Profession					
Doctor/Nurse	0 (0.0)	9 (22.0)	81 (43.1)	151.55	<0.001
CHEW/DSNO	10 (12.5)	32 (78.0)	40 (21.3)		
Record officers	70 (87.5)	0 (0.0)	67 (35.6)		
PHC					
Rural	10 (12.5)	41 (100.0)	117 (62.2)	212.79	<0.001
Semi-Urban	17 (21.3)	0 (0.0)	71 (37.8)		
Urban	53 (66.3)	0 (0.0)	0 (0.0)		

Table 3 presents an analysis of the socio-demographic factors that influence the adoption of digital health tools. The factors are categorized into three domains: Logistics & Supply Chain Management, Disease Surveillance & Response Systems, and Data Collection, analytics, visualization & use.

The analysis demonstrated a highly significant relationship between age and adoption in all three domains (χ^2 = 203.64, p <

0.001). The majority of individuals in the Logistics & Supply Chain Management field were 51 years of age or older, with 57.5% of the workforce. Conversely, the younger age groups, specifically those between 21 and 30, were underrepresented. In contrast, respondents aged 31-40 exhibited a predominant adoption rate of 78.0% for the Disease Surveillance & Response Systems. The instruments for Data Collection & Health Information Management were primarily used by respondents in the 41-50 age range, which comprised 41.0% of users. Males constituted the majority of users in Data Collection & Health Information Management (76.6%), and they were entirely dominant in the Disease Surveillance & Response Systems (100.0%).

Furthermore, the adoption of digital health instruments was significantly influenced by sex (χ^2 = 136.92, p < 0.001). The primary consumers of all three systems were individuals in marital relationships, particularly in Logistics & Supply Chain Management (96.3%) and Data Collection & Health Information Management (71.3%) (χ^2 = 44.64, p < 0.001). Adoption was significantly influenced by the level of education (χ^2 = 8.37, p = 0.007). In all areas, individuals with tertiary education exhibited virtually complete adoption. They achieved 100% adoption in both

Disease Surveillance & Response Systems and Data Collection & Health Information Management, as well as 95.0% adoption in Logistics & Supply Chain Management. The respondents with the highest level of IT expertise were the primary adopters of Logistics & Supply Chain Management, with 83.8% of the sample. Conversely, those with the least knowledge were predominantly engaged in Disease surveillance and response, which was statistically significant (χ^2 = 228.22, p < 0.001). The adoption of digital health instruments was significantly influenced by the role of profession (χ^2 = 151.55, p < 0.001). Record officers primarily employed Logistics & Supply Chain Management (87.5%), while CHEW/MRO/DSNO professionals primarily adopted Disease Surveillance & Response Systems (78.0%). Healthcare personnel exhibited a higher propensity to employ Data Collection & Health Information Management (43.1%). Data Collection & Health Information Management was significantly adopted in semi-urban regions (37.8%), while rural primary health centers were the primary implementers of Disease Surveillance & Response Systems (100.0%). The adoption of Logistics & Supply Chain Management was significantly represented in urban centers, with a percentage of 66.3% and p < 0.001.

Table 4. Association between Users' Perceptions, Literacy, and Experiences in Implementing and Adopting the Digital Health Tools

Independent variables	Dependent variables Digital health tools in used	Estimate	p-value
Perceived Usefulness	Disease Surveillance & Response Systems	-.116	0.04
IT Knowledge	Disease Surveillance & Response Systems	.082	0.15
Education	Disease Surveillance & Response Systems	.017	0.77
Perceived Usefulness	Data Collection & Health Information Management	.183	<0.001
IT Knowledge	Data Collection & Health Information Management	-.205	<0.001
Education	Data Collection & Health Information Management	.155	0.004
Perceived Usefulness	Logistics & Supply Chain Management	-.002	0.96
IT Knowledge	Logistics & Supply Chain Management	.712	<0.001
Education	Logistics & Supply Chain Management	-.317	<0.001

Association between Users' Perceptions, Literacy, and Experiences in Implementing and Adopting the Digital Health Tools

The associations between the implementation of digital health tools and users' perceptions, IT knowledge, and education levels are illustrated in Table 9 and Figure 2 below. The use of tools for data collection and health information management was significantly associated with user perception of the usefulness of digital health tools (Estimate: 0.183, p-value: <0.001). However, there was no significant effect in the area of Logistics and Supply Chain Management (Estimate: -0.002, p-value: 0.96). In addition, IT Knowledge exhibits a positive correlation (Estimate: 0.082, p-value: 0.15) with Disease Surveillance & Response Systems tools and a stronger correlation (Estimate: 0.712, p-value: <0.001) with Logistics & Supply Chain Management tools. However, this pattern does not hold for Education.
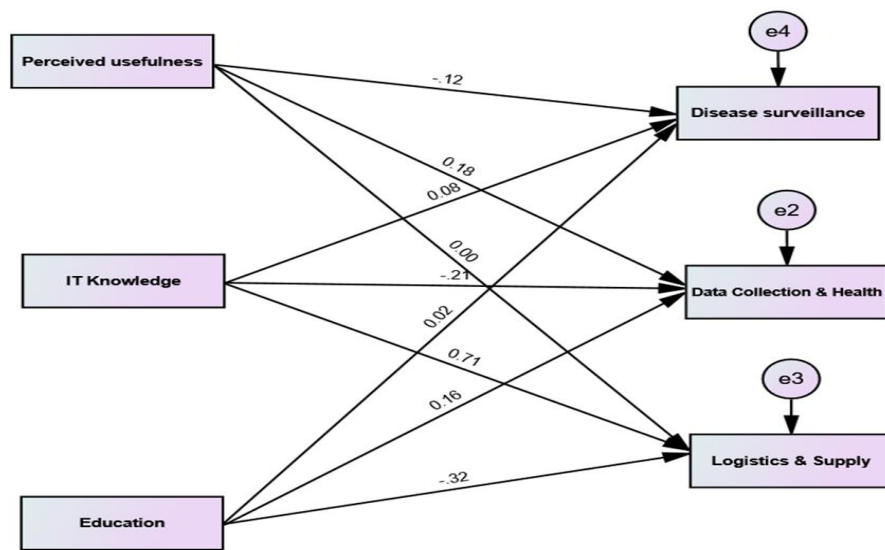

Figure 1: Pathway Analysis to Access actual Users' Perceptions, Literacy, and Experiences in Implementing and Adopting the Digital Health Tools.

Discussion

The demographic characteristics of the individuals selected for this study from various primary health facilities across three states in Northern Nigeria are notably significant.

The majority of participants, 105 (34.0%), were between the ages of 31 and 40. This finding is consistent with the research conducted by [23]. The age group of 31-40 is particularly significant because it frequently represents a techno-savvy and professionally active segment of the population, which is essential for the sustainable adoption of digital health tools. Most of the health practitioners, 195 (63.1%), were male.

This finding is typical in other developing countries [24], [25], but it is not the case in developed countries, where people of both sexes have rights that are nearly equivalent to one another [26], [27].

The World Health Organization reports that 70% of the worldwide health workforce comprises females, a phenomenon referred to as the feminization of healthcare occupations. In Nigeria, women represent the predominant demographic among medical doctors and nursing and midwifery personnel, according to data from 2018 indicating that 65% of physicians and 87% of nursing staff were female [28]. Nonetheless, Trained healthcare workers on the frontlines in Northern Nigeria are predominantly male because of insufficient educational attainment among girls. The gender imbalance among healthcare professionals in Northern Nigeria is a critical concern. The

region encounters obstacles, including less educational achievement among girls, which constrains their prospects of becoming skilled healthcare professionals. Consequently, the majority of skilled healthcare professionals are male [29].

Conversely, a significant number of unskilled healthcare workers, including community health volunteers, are primarily female. This circumstance is shaped by cultural norms and the restricted presence of female healthcare practitioners [29].

Initiatives to rectify this discrepancy encompass enhancing educational possibilities for girls and fostering community involvement to endorse the acceptance of healthcare services provided by male frontline health workers [30].

In addition, a substantial proportion of participants were married, with 243 (78.6%) and 305 (98.7%) having completed at least tertiary educations. This indicates a well-educated and potentially stable demographic, which may positively influence the sustained use of these tools. The adoption and sustainable use of digital health instruments in primary healthcare centers in Nigeria can be influenced by a variety of factors, including the marital status of healthcare workers. Healthcare professionals who are married frequently balance their professional obligations with their family obligations. This dual role can have an impact on their capacity to engage with and implement new technologies, particularly if these tools necessitate additional training or time investment [31].

Furthermore, the tension associated with the adoption of new technologies may be mitigated by the fact that married individuals may have more robust support systems at home. This assistance may be provided by spouses or extended family members who assist in the management of domestic responsibilities.

Marriage can offer a sense of motivation and stability. Healthcare professionals may be more inclined to adopt digital health tools that can enhance their work efficiency and patient care

when they feel supported at home [31]. It is interesting to note that the adoption of digital health instruments is contingent upon the availability of training and ongoing professional development. Healthcare professionals who are married may encounter difficulties in attending training sessions as a result of family obligations, which may impact their proficiency with these tools.

The success of the adoption of digital health tools is also contingent upon the policies and support supplied by healthcare institutions. Married healthcare professionals can more effectively engage with digital health initiatives and balance their responsibilities by utilizing flexible work schedules, on-site childcare, and other supportive measures.

In general, the key to sustainable adoption is the establishment of an environment that accommodates the diverse needs and circumstances of healthcare workers, despite the fact that marital status can present both challenges and advantages.

In addition, 109 respondents (35.3%) exhibited a minimum level of IT knowledge. There is a similarity between this and a study that was carried out in one of the Northern States of Nigeria [24]. A number of factors have an impact on the minimum level of information technology proficiency of primary health workers in Northern Nigeria: The majority of primary health care institutions in Northern Nigeria are confronted with considerable resource limitations, such as insufficient financing for information technology infrastructure and training [32]. This makes it more difficult to provide health staff with the appropriate information technology skills and tools. It is common for there to be a dearth of all-encompassing training programs that are centered on information technology skills for those who work in the health care industry. It's possible that the training programs that are currently available don't effectively address the utilization of digital tools and technology that

are necessary for the delivery of modern healthcare [32].

It is possible that the region has limited access to dependable internet and energy, both of which are essential for the efficient utilization of information technology in the healthcare industry. In addition, the development and utilization of information technology solutions are both hampered by this infrastructure gap.

Although there are national standards and policies that are aimed at enhancing primary healthcare, the implementation of these policies and standards at the local level might be inconsistent.

It is necessary to develop targeted interventions in order to address these difficulties. These interventions should include greater financing, enhanced training programs, improved infrastructure, and effective policy implementation in order to strengthen the information technology capabilities of primary health workers in Northern Nigeria.

The majority of health centers, 168 (54.4%), were situated in rural areas and utilized at least one digital health tool. It is generally accepted that a sizeable percentage of PHCs in northern Nigeria are situated in villages and other rural areas. In comparison to metropolitan inhabitants, rural populations frequently encounter more obstacles while attempting to gain access to healthcare. The purpose of this distribution is to improve access to healthcare services for rural populations.

As part of broader efforts to improve health equity and guarantee that marginalized groups access vital health services [33], the focus on rural areas is a component of those general efforts. Nevertheless, the availability of services and the quality of such services might substantially fluctuate from one region and facility to another [34].

Across all three domains, the analysis demonstrated a highly significant relationship between age and adoption (χ^2 = 203.64, p < 0.001). Thus, our research indicates that the age of individuals in Nigeria and sub-Saharan Africa can significantly influence their adoption of digital health solutions. It is crucial to note that the age group of 31-40 years was the greatest group of participants, with a total of 105 individuals, accounting for 34.0% of the sample. The utilization of digital health solutions is more prevalent among younger individuals employed in the health care sector. They are generally more inclined to integrate new digital solutions into their daily routines and possess a greater understanding of technology. Additional research has identified a statistically significant correlation between the age of the participants [22], [35]. This is in minor contrast to the results that digital device usage was correlated with older age [31]. The adoption of digital health solutions may present more challenges for older health professionals than for their younger counterparts. This may be the consequence of a desire for more traditional methods, an aversion to change, or a lack of familiarity with digital technology.

By offering older health personnel appropriate training and assistance, it is feasible to facilitate their adoption and utilization of digital health solutions in an effective manner.

In addition, this investigation underscores the substantial variables that determine the adoption of digital health instruments, including marital status, education level, IT proficiency, occupation, and geographic location. The findings indicate that the adoption of digital health instruments is significantly influenced by sex (χ^2 = 136.92, p < 0.001), with persons in marital relationships being the primary users of all systems. The level of education also emerged as a critical factor, with individuals who have completed tertiary education exhibiting virtually complete adoption in all areas, particularly in data collection, analytics, and visualization; logistics and supply chain management, and disease surveillance and response systems (χ^2 = 8.37, p = 0.007).

Sex's considerable influence on the adoption of digital health tools is in accordance with the World Health Organization's evaluation of the role of digital health technologies in promoting gender equality and improving the health of women [36]. Moreover, the willingness of healthcare personnel to utilize digital health tools was significantly correlated with their gender [22],[23].

However, marital status also came to be a significant determinant, as individuals in marital relationships were the primary users of all three systems. The utilization of digital health tools for the effective administration of healthcare may be attributable to the increased health management responsibilities that are frequently associated with family life.

Education level emerged as a significant factor, with respondents who possess higher education degrees exhibiting nearly complete adoption in all domains. This is consistent with the results of other research that suggests that improved access to resources and enhanced digital literacy are associated with increased technology adoption, which is attributed to advanced educational attainment. The full adoption rate of the categorized domains of digital health tools, among individuals with higher education underscores the importance of educational achievement in facilitating the use of advanced health technologies. A study was conducted to investigate the influence of digital health platforms on the improvement of healthcare delivery in Africa, underscoring the importance of education and training in the successful implementation of these technologies [37].

The methodology for scoping reviews outlined the impact of digital health interventions on health systems and the importance of higher education in facilitating the successful adoption and implementation of these tools [38].

The necessity of healthcare professionals' education and training is underscored, as it examines the implementation of a variety of digital health applications in numerous countries, including Nigeria [39].

Respondents with advanced IT skills exhibit the greatest adoption rates (83.8%), which is indicative of the significant impact of IT expertise on the adoption of logistics and supply chain management tools. This result is consistent with research that suggests technical proficiency is essential for the effective utilization of digital health tools [9], [23]. In Sub-Saharan Africa, the success of digital health will be contingent upon the health workforce's proficiency in digital technologies [40]. In contrast, individuals with limited IT expertise were primarily involved in disease surveillance and response, which emphasizes the need for specialized training initiatives to address these skills divide.

The profession's influence on the adoption of digital health tools was significant ($\chi^2 = 151.55$, $p < 0.001$). The subsequent research revealed that a variety of healthcare practitioners [9], [23], [35] utilize digital tools. The importance of profession was underscored by our research, as record officers primarily employed logistics and supply chain management (87.5%), while CHEW/DSNO professionals mostly employed disease surveillance and response systems (78.0%). Various professional positions within the healthcare system are associated with distinct requirements and responsibilities, as evidenced by the observed patterns.

Adoption rates were significantly influenced by the geographical location, as rural primary health centres demonstrated exceptional proficiency in the implementation of disease surveillance and response systems, attaining an impressive 100.0% rate ($\chi^2 = 212.79$; $p < 0.001$). The findings slightly contradict research, which posits that metropolitan regions generally have superior infrastructure and resources to encourage the adoption of advanced digital health technologies [41]. This information can be used to guide future research and development initiatives, ensuring

that digital health solutions are both effective and accessible.

Further, the adoption of digital health tools was positively correlated with IT knowledge. Although there was a moderate positive correlation between IT knowledge and the utilization of Disease Surveillance & Response Systems tools (Estimate: 0.082, p-value: 0.15), this correlation did not attain statistical significance. A substantial positive correlation was observed between the utilization of Logistics and Supply Chain Management tools and IT knowledge (Estimate: 0.712, p-value: <0.001). This pattern highlights the importance of IT proficiency in the effective administration of logistics and supply chain processes in the healthcare sector.

In the Education domain, the anticipated pattern of associations was not observed, indicating that the adoption and implementation of digital health tools in the assessed areas were not substantially influenced by education levels.

Conclusion

The adoption of digital health instruments is significantly influenced by socio-demographic factors, as this study emphasizes. The analysis indicates that the adoption of digital health technologies is significantly influenced by factors such as age, sex, marital status, level of education, IT knowledge, and professional background. These results underscore the necessity of targeted strategies that take into account these socio-demographic variables in order to improve the adoption of digital health tools.

The adoption of digital health tools is intricate, influenced by a diverse array of demographic, educational, professional, and geographical factors, as evidenced by the examination of these findings in conjunction with other studies.

The findings of this study underscore the complex interplay of numerous factors that influence the adoption of digital health technologies in Nigeria. It is important to address these factors through targeted interventions, such as the improvement of IT training, the enhancement of digital literacy, and the guarantee of equitable access across multiple regions, in order to fully capitalize on the benefits of digital health technologies. It is critical to consider the unique requirements and preferences of various demographic groups in order to ensure the successful implementation of these technologies. For example, IT knowledge and skills can be enhanced among healthcare professionals through customized training programs, which in turn enhances their preparedness and capacity to effectively utilize digital health tools. Moreover, inclusive policies that address the specific obstacles encountered by different demographic groups can foster a more equitable distribution of access to digital health solutions. Policymakers, healthcare providers, and stakeholders can create interventions that are more sustainable and effective by comprehending and utilizing the socio-demographic factors that influence the adoption of digital health tools. This method not only enhances healthcare outcomes but also guarantees that digital health technologies are accessible to and advantageous to all demographics, thereby fostering greater health equity and more resilient healthcare systems.

Conflict of Interest

None declared.

Acknowledgements

References

[1]. UNICEF. 2020. Digital health and digital engagement for COVID-19 preparedness and response. New York: UNICEF.

[2]. Federal Government of Nigeria. 2019. Second National Strategic Health Development Plan 2018-2022. Federal Government of Nigeria.

[3]. Shuaib, F., Rajni, G., Musa, E. O., Mahoney, F. J., Oguntimehin, O., Nguku, P. M., Nasidi, A. 2014. Ebola Virus Disease Outbreak — Nigeria, July–September 2014. Atlanta: Centers for Disease Control and Prevention: Morbidity and Mortality Weekly Report (MMWR).

[4]. World Health Organization. 2019. Report of the Global Conference on Primary Health Care: from Alma-Ata towards universal health coverage and the (WHO/UHC/SDS/2019.62). Geneva: World Health Organization.

[5]. ITU. 2021. ICTs and Digital Health. From ITU Web site: https://www.itu.int/en/mediacentre/backgrounders/Pages/icts-digital-health.aspx.

[6]. World Health Organization. 2016. Monitoring and evaluating digital health interventions: a practical guide to conducting research and assessment. WHO: Geneva.

[7]. HealthIT. (n.d.). Public health focuses on preventing disease, diagnosing health conditions, and promoting health. From HealthIT.gov Web site: https://www.healthit.gov/topic/health-it-health-care-settings/public-health.

[8]. World Health Organization. 2016. International Health Regulations (2005). (3rd ed.). Geneva: WHO

[9]. Zayyad, M., & Toycan, M. (2018). Factors affecting sustainable adoption of e-health technology in developing countries: an exploratory survey of Nigerian hospitals from the perspective of healthcare professionals. *PeerJ*.

[10]. Nieukwerk, v. A. (2019, August Accessed April 16 2023). Africa's approaches to crisis management are unique when it comes to dealing with disease. From World Economic Forum: https://www.weforum.org/agenda/2019/08/how-to-manage-in-a-crisis-lessons-from-the-west-africa-ebola-outbreak/.

[11]. Nigeria Centre for Disease Control. (2024). An update of cholera outbreak in Nigeria. From NCDC: https://ncdc.gov.ng/diseases/sitreps/?cat=7&name=An%20update%20of%20Cholera%20outbreak%20in%20Nigeria.

[12]. Goode, E., Thomas, E., & Landeg, O. E. 2021. Development of a Rapid Risk and Impact Assessment Tool to Enhance Response to Environmental Emergencies in the Early Stages of a Disaster: A Tool Developed by the European Multiple Environmental Threats Emergency NETwork (EMETNET) Project. Int J Disaster Risk Sci, 528-539.

[13]. Noah, N. 2021. Surveillance of Infectious Diseases. Encyclopedia of Virology, 247-55.

[14]. World Health Organization. 2018. Progress Report on Utilizing E-Health Solutions to Improve National Health Systems in the African Region. WHO.

[15]. Jameela A, N. M. 2020. Health 4.0: On the Way to Realizing the Healthcare of the Future. IEEE Access.

[16]. Emnify. 2021. An Introduction to Industry 4.0. From Emnify Web site: https://www.emnify.com/blog/industry-4-0.

[17]. Khalil, H., & Kynoch, K. 2021. Implementation of sustainable complex interventions in health care services: the triple C model. *BMC Health Serv Res*.

[18]. Probasco, J. 2023. *Why Do Healthcare Costs Keep Rising?* From Investopedia Web site: https://www.investopedia.com/insurance/why-do-healthcare-costs-keep-rising/.

[19]. Digital Health Africa. 2021. Expanding The Scope Of Health Care Services With Effective Digital Health Technologies. From Digital Health Africa Web site: https://www.biihealthtech.com/digihealthafrica/.

[20]. Olu, O., Muneene, D., Bataringaya, J. E.,Turgeon, Y. 2019. How can digital health technologies contribute to sustainable attainment of universal health coverage in Africa? A perspective. *Front Public Health*.

[21]. Karamagi, H., Muneene, D., Droti, B., Jepchumba, V., Okeibunor, J., Nabyonga, J., Kipruto, H. 2022. eHealth or e-Chaos: The use of

Digital Health Interventions for Health Systems Strengthening in sub-Saharan Africa over the last 10 years: A scoping review. *J Glob Health*.

[22]. Love B. Ayamolowo, L. B., Irinoye, O. O., & Olaniyan, A. S. 2023. Utilization of electronic health records and associated factors among nurses in a faith-based teaching hospital,Ilisan, Nigeria. *JAMIA Open*.

[23]. Akwaowo, C., Sabi, H., Ekpenyong, N., Isiguzo, C., Andem, N., Maduka, O., . . . Uzoka, F. 2022. Adoption of electronic medical records in developing countries—A multi-state study of the Nigerian healthcare system. *Front. Digit. Health*.

[24]. Ahmed MA, M. M. 2022. Assessment of information communication technology and eHealth use amongst healthcare providers in selected primary health centers in Kano, Nigeria. *Journal of Basic and Social Pharmacy Research*.

[25]. Sanqui, R., & Declaro-Ruedas, M. 2020. Knowledge and attitudes towards healthcare information technology of the rural health workers in SAMARICA, Occidental Mindoro, Philippines. . *Asian Journal of Education and Social Studies*.

[26]. Jain, R., Dupare, R., Bhanushali, N., & Kumar, V. 2020. Knowledge and utilization of computer among health-care professionals in Mumbai. *Journal of Indian Association of Public Health Dentistry*.

[27]. Shiferaw, K., Tilahun, B., & Endehabtu, B. 2020. Healthcare providers' digital competency: a cross-sectional survey in a low-income country setting. *BMC Health Sevices Research*.

[28]. World Health Organization. 2023. *Sex distribution of health workers*. From WHO Web site: https://apps.who.int/gho/data/node.main.HWFGRP_BYSEX?lang=en.

[29]. World Health Organization. 2018. *The invisible boys and girls: Understanding barriers to accessing healthcare among disadvantaged Nigerian youth*. From WHO Web site: https://www.afro.who.int/news/invisible-boys-and-girls-understanding-barriers-accessing-healthcare-among-disadvantaged.

[30]. Okereke, E. U. 2020. Female clients' gender preferences for frontline health workers who provide maternal, newborn and child health (MNCH) services at primary health care level in Nigeria. *BMC Health Serv Res*.

[31]. Blondino, C. K. 2024. The use and potential impact of digital health tools at the community level: results from a multi-country survey of community health workers. *BMC Public Health*.

[32]. Sampson, S. U.-J. 2024. Assessment of the compliance with minimum quality standards by public primary healthcare facilities in Nigeria. *Health Res Policy Sys*.

[33]. Ogah, P. U. 2024. Primary health care in Nigeria: best practices and quality of care in Nigeria. *BMC Health Serv Res*.

[34]. Ekenna, A., Itanyi, I., Nwokoro, U., Hirschhorn, L. R., & Uzochukwu, B. 2020. How ready is the system to deliver primary healthcare? Results of a primary health facility assessment in Enugu State, Nigeria. *Health Policy and Planning*, Pages i97–i106.

[35]. Ojo, et al. 2022. 'Perception of Healthcare Workers on the Integration of Electronic Health Records in Primary Health Centers in Nigeria. *CIN - Computers Informatics Nursing*, 786-794.

[36]. World Health Organization. 2024. Digital tools can help improve women's health and promote gender equality, WHO report shows. From WHO Web site: https://www.who.int/europe/news/item/08-03-2024-digital-tools-can-help-improve-women-s-health-and-promote-gender-equality--who-report-shows.

[37]. Ibeneme, S., Karamagi, H., Muneene, D., Goswami, K., Chisaka, N., & Okeibunor, J. 2022. Strengthening health systems using innovative digital health technologies in Africa. *Frontiers in Digital Health*.

[38]. Kipruto, H., Muneene, D., Droti, B., Jepchumba, V., Okeibunor, C. J.-O., & Karamagi, H. C. 2022. Use of Digital Health Interventions in Sub-Saharan Africa for Health Systems Strengthening Over the Last 10 Years: A Scoping Review Protocol. *Frontiers in Digital Health*.

[39]. Owoyemi, A., Osuchukwu, J. I., Azubuike, C., Ikpe, R. K., Nwachukwu, B. C., 2022. Digital Solutions for Community and Primary Health

Workers: Lessons From Implementations in Africa. Frontiers in Digital Health.

[40]. Owhor, G. A., Abdulwahab, A. A., Shomuyiwa, D. O., & Okoli, E. A. 2023. Overview of Digital Health in Sub-Saharan Africa: Challenges and Recommendations. *IOSR Journal of Nursing and Health Science (IOSR-JNHS)*, 19-21.

[41]. Ravi, N., Thomas, C., & Odogwu, J. 2024. How to reload and upgrade digital health to serve the healthcare needs of Nigerians. *Frontiers in Digital Health*.