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Research Article

Applications of Digital Mobile Technologies in Response to the COVID-19 Pandemic: Some Evidence from Frontline Healthcare Workers in Three Tertiary Hospitals in Ghana

Yiqun Geng [1*]
0000-0002-0891-3563

John Demuyakor [1]
0000-0002-6084-6951

[1] Institute of Communication Studies, Communication University of China, Beijing, CHINA
[*] Corresponding author: gengyiqun@cuc.edu.cn

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ABSTRACT

The World Health Organization (WHO) declared the COVID-19 pandemic a public health disaster of global concern on the 30th January 2020. With the highly infectious COVID-19 virus inevitably spreading across nations and causing significant health and economic impacts, leveraging Digital Mobile Technologies (DMTs) by frontline healthcare practitioners has been touted as a lifeline. Since January 2020, various frontline health workers, health experts, and health institutions across the globe have progressively embraced the use of numerous DMTs as an essential means of restraining the highly infectious disease spread. DMTs such as smart mobile phones and other digital mobile technologies are the reliable means of sharing pertinent health information, awareness, and surveillance as well as facilitating access to crucial healthcare services, especially in designated COVID-19 health facilities. Therefore, this study employed, an online survey using an exploratory-based research design to investigate how the COVID-19 pandemic has revolutionized the usage of DMTs among (n=1,126) frontline healthcare practitioners in three leading tertiary hospitals in Ghana. We adopted technology acceptance model (TAM) to study the adoption and utilization of DMTs and their limitations by frontline healthcare workers in COVID-19 management. We found that 75.1% (n=846 out of 1,126) of frontline healthcare workers, comprising nurses, medical doctors, physician assistants, and COVID-19 contact tracers were aware of DMTs, adopted and used DMTs in response to the COVID-19 pandemic and its management. However, 93.0% (n=784 out of 846) of those who were aware of the DMTs employed them in their daily operations beyond the fight against the COVID-19 pandemic. Our analyses also indicate that increased usage of these DMTs has significantly enhanced public healthcare campaigns and education on the COVID-19 pandemic in Ghana. These mobile applications have also improved and boosted healthcare communications among practitioners on measures against the COVID-19 pandemic. In terms of originality, this study expands our understanding of digital technology in response to the COVID-19 Pandemic in less studied regions such as Africa, West Africa, and Ghana to be specific. Secondly, the study contributes to filling a gap in our understanding of how theories such as TAM function in crisis communication management. Finally, the study recommends health authorities and governments in developing countries incorporate DMTs in their current health care systems, especially in public health emergencies like COVID-19 preparedness.

Keywords: COVID-19, digital mobile technologies, frontline healthcare practitioners, COVID-19 management, public health emergencies, Ghana

INTRODUCTION

The World Health Organization (WHO) declared COVID-19 a public health disaster of global concern on the 30th January 2020. Subsequently, various health experts and health institutions globally embraced the use of numerous digital mobile technologies (DMTs) as essential tools in response to this highly infectious disease spread (CDC, 2020; Gasser et al., 2020; WHO, 2020a). Since then, health facilities and healthcare workers in Ghana have embraced digital technologies in the provision of healthcare services amidst the outbreak of the COVID-19 pandemic (Cory & Stevens, 2020; Demuyakor, 2020). The public healthcare sector in Ghana is structured based on the traditionally indispensable model of direct physical interactions between clinicians and their patients (Owusu, 2020). Clinical workflows, as well as financial incentives, have principally been established to support and bolster a direct healthcare model, leading to the usual 'massing' of patients in the outpatient units and the emergency departments during a health crisis (CDC, 2020; WHO, 2020b). With the promotion of the "*Ghana Go Digital Agenda*," the Ghanaian government's digital policy has significantly invigorated the health ministry, health facilities, and healthcare workers nationally to embrace digital technologies in the provision of healthcare services amidst the outbreak of the COVID-19 pandemic (Cory & Stevens, 2020). This study assesses how the COVID-19 pandemic in Ghana has instigated the adoption and utilization of DMTs among frontline health workers within the Greater Accra Regional Hospital, Okomfo Anokye Teaching Hospital, and Tamale Teaching Hospitals which were among the key referral hospitals in response to the COVID-19 pandemic.

LITERATURE REVIEW

Awareness and Application of DMTs in Response to COVID-19

According to Romero-Rodríguez et al. (2020), DMTs are defined as digital technology-mediated devices or technologies for knowledge acquisition and enhancing digital competence. DMTs focus mostly on applying information communication technologies (ICT) to promote autonomy and collaboration between users. As various public healthcare systems worldwide anticipated an increase in COVID-19 cases in the first half of 2020, speedy action was required to transform healthcare delivery and improve healthcare systems by exploiting innovative mobile healthcare technologies. While various digital healthcare technologies (DHTs), including those employed in telemedicine, have been available for decades, Cory and Stevens (2020) indicate their poor market penetration and adoption, a factor that is attributed to the high regulations and supportive payment structures. In response to the COVID-19 pandemic, it is recommended that frontline health workers adopt and use vital digital mobile applications such as visualization data dashboards, apps for extracting data, all forms of applications for medical reporting, and survey apps (WHO, 2020c). Frontline health workers use DMTs for rapid case identification, point-of-care diagnosis, and febrile symptoms checking (Budd et al., 2020; Chua et al., 2020; WHO, 2020c). For regular and continuous digital contact tracing, experts recommend that frontline health workers use DMTs such as low-power Bluetooth technology and smartphone app. For mobility-pattern analysis of COVID-19-related deaths digital mobile tools such as mobile-phone-location data will be required. For public health communication, frontline health workers utilize social-media platforms, online search engines, and chat bots for targeted communication, prioritized information, and personalized information sharing (Galle et al., 2021; Owusu, 2020; Whitelaw et al., 2020).

DMTs Used by Frontline Health Workers for COVID-19 Pandemic Response

The COVID-19 pandemic has compelled the global community to introduce digital mobile technologies, such as telehealth and e-health, which can contribute to the management of diseases during the pandemic and possibly reduce the rate of infection of COVID-19, and encourage social distancing (Owusu, 2020; WHO, 2020a). The adoption of these digital mobile technologies in response to the pandemic is on record to have helped reduce the physical involvement of health professionals in managing COVID-19 patient care in health facilities across the globe (Huang et al., 2020; Vaishya et al., 2020; Yu et al., 2020). The application of these remote digital mobile technologies has supported the difficult balance of maintaining social distancing and continuing to support COVID-19 patients, and those caring for them, but has also enabled a significant cost reduction to the health system and decreased the risk of infections (Budd et al., 2020; Krishna et al., 2020; Owusu, 2020; WHO, 2020a).

Frontline health professionals have adopted and continued to use several digital mobile technologies such as video telehealth, videoconferencing, and technology-based behavioral interventions for quick and rapid response to the rehabilitation of COVID-19 patients (Kopelovich, & Turkington, 2021; Varela-Aldás et al., 2021).

These digital mobile technology-based interventions in response to the COVID-19 pandemic have proven to be one of the surest means of reducing the COVID-19 pandemic spread among both frontline health workers and the general population. The adoption of digital mobile technologies and applications has again enabled frontline health workers to achieve prevention, early detection, care, management, and diagnosis of infections of the COVID-19 pandemic. The applications of these digital technologies by COVID-19 frontline health workers have drastically helped to reduce physical contact (Chua et al., 2020; Whitelaw et al., 2020).

The COVID-19 crisis has provided the opportunity to embrace digital mobile technologies, to support frontline health workers in COVID-19 designated hospitals to maintain communications with affected persons during self-isolation (Krishna et al., 2020; Whitelaw et al., 2020). Health policymakers, service providers, and clinicians adopt these innovative opportunities and support the technological transformation during COVID-19 infections (Krishna et al., 2020). In hospital settings, the application of digital mobile technologies has proven to be the best way of managing COVID-19 infections, supporting a reduction, and aiding in offering the best clinical care to affected COVID-19 patients (Gerke et al., 2020). Bearing in mind the central role of the application of digital mobile technologies in response to the COVID-19 pandemic, a good number of countries have invented and adopted various digital mobile technologies to support the control and management of the pandemic (Horgan et al., 2020; Kapoor et al., 2020; Krishna et al., 2020; WHO, 2020b).

DMTs and Usefulness for COVID-19 Pandemic Response

Gasser et al. (2020) and Wilson (2020) indicated that digital mobile health technologies and mobile applications have certainly the potential to become very powerful healthcare tools. The most common DMT utilized by most healthcare workers comprises electronic medical records, electrical health records laboratory information systems, clinical software applications, text, email, video calling, and video conferencing innovations. These particular advancements enable smartphones to be utilized as diagnostic tools, and to access public healthcare services (Alwashmi, 2020; Gasser et al., 2020; Siriwardhana et al., 2020; WHO, 2020c).

Several countries adopted digital tools to aid in COVID-19 management and control. For instance, Ghana (*GH COVID-19 Tracker App*), Austria (*Stopp Corona App*), Australia (*COVIDSafe App*), China (*Close Contact Detector App*), Germany (*Corona-Warn App*), Singapore (*TraceTogether App*), and Switzerland (*SwissCovid App*) (Owusu, 2020). The *GH COVID-19 Tracker App* launched in Ghana by the Ministry of Communications is available for voluntary download from Apple Store [iOS] and Google Playstore [Android] (Owusu, 2020). This app uses Bluetooth and GPS technologies to provide geographically detailed information on COVID-19 incidence (s) and location after a potential exposure (Owusu, 2020).

Budd et al. (2020) and Huang et al. (2020) alluded that the application of digital mobile technologies in response to COVID-19 has enabled frontline health workers to make some critical clinical decisions, diagnoses and outcomes to be supported in a timelier manner, supporting earlier intervention opportunities to support and improve response to the COVID-19 pandemic. The adoption of digital mobile technologies can also contribute to the reduction of the burden on healthcare institutions and frontline health professionals (Dean, 2021; Galle et al., 2021). In Ghana, for instance, drones were applied in transporting COVID-19 personal protective equipment, medicines, and vaccines to rural and hard-to-reach areas (Owusu, 2020).

According to Galle et al. (2021), direct and indirect benefits are derived from the application of digital mobile technologies such as telehealth to track symptoms, promote physical distancing, and timely detection of the COVID-19 pandemic. The COVID-19 crisis has shown further those emerging technologies like the internet-of-things and artificial intelligence are essential to the functioning of our society and economy in this 21st century (Bettinger, 2020; Vaishya et al., 2020). Digital technology facilitates education and sensitization of frontline health workers and the general public to follow better care with limited resources and dissemination of accurate information (Krishna et al., 2020; Whitelaw et al., 2020).

Limitations of Using DMTs for COVID-19 Pandemic Response

DMTs and mobile applications used on health initiatives may augment social-economic inequalities and consequently contribute significantly to healthcare inequalities. Digital mobile technology entails the utilization of mobile phones and the internet. Even though about four billion persons use the internet globally in the year 2019, the consumption was disproportionately higher within high-income countries as compared to lower-income and middle-income countries; 82% in the European continent versus 28% in the African

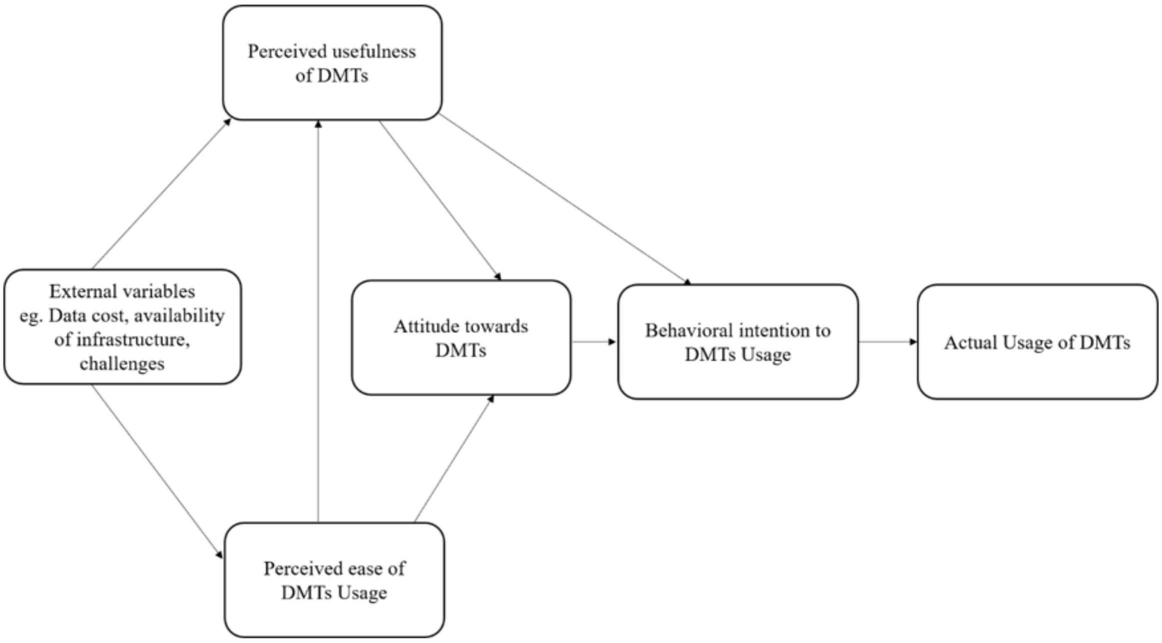

Figure 1. Research model

continent (Haleem et al., 2020). Equally, Haleem et al. (2020) suggested that in areas lacking infrastructure or adequate funds to facilitate cellular and access to the internet, devices, and applications that do not necessarily require unlimited internet access should be given significant consideration. Use of DMTs and apps come with risks and limitations of which few have been documented (Budd et al., 2020; Gerke et al., 2020).

THEORETICAL FRAMEWORK

The utilization of DMTs within the public healthcare sector has become increasingly essential due to technological transformation. DMTs through the internet support electronic prescriptions, electronic health records, and digitally organized communication structures within the healthcare sector (Safi et al., 2019). Again, the use of DMTs in the provision of public healthcare services faces various obstacles, including end-user acceptance. According to Davies (1989), TAM is a means of studying digital technology adoption and usage. This model proposes that when users are offered a new technology, their use is dependent on several factors. Among these factors include behavioral intentions, attitude, and perceived usefulness of the system, perceived ease of use of the innovation, individual user's intention, and facilitating organizational condition (**Figure 1**).

The attitude of a user towards technology or innovation is dependent on whether the user will utilize or reject the innovation. The attitude of the user, in turn, is influenced by

(a) perceived usefulness and

(b) perceived ease of use, with a direct effect on perceived usefulness.

The perceived usefulness and perceived ease of use are also determined by external variables such as cost of data, availability of facilities, and associated challenges of the technology or innovation. Davies (1989) noted that an end-user's intention to use an innovation establishes two major factors that influence the approval of an application; perceived usefulness and perceived ease of application. As highlighted by Davies (1989), TAM was developed from the reasoned action theory, a theory that aims at explaining users' behavior. With TAM as a foundation model from several innovation adoptions and acceptance studies, this present study adopted TAM as the main theoretical framework to assess digital mobile technologies adoption and usage in response to the COVID-19 global pandemic by frontline healthcare workers in three topmost tertiary hospitals in Ghana. Adoption of TAM for this study allowed for the inclusion of five major research questions with the specific objectives of establishing acceptance and usage of DMTs by healthcare workers in the three tertiary hospitals in Ghana.

Research Questions (RQ)

1. **RQ1.** What is the level of awareness and usage of DMTs in response to COVID-19 among healthcare practitioners in Ghana?
2. **RQ2.** What is the specific usage of DMTs during the COVID-19 outbreak in Ghana?
3. **RQ3.** What is the perceived usefulness of these DMTs in response to the COVID-19 outbreak?
4. **RQ4.** What are the usage determinants of these DMTs in response to the COVID-19 outbreak among healthcare workers?
5. **RQ5.** What are the limitations of the usage of these DMTs in response to the COVID-19 outbreak?

MATERIALS AND METHODS

Participants and Study Area

Participants (n=1,126) were nurses (28.2%), biomedical scientists (27.7%), medical doctors (23.6%), physician assistants (12.3%), and the remaining 8.2% comprised para-hospital workers including cleaners, monitoring, and evaluation officers, administrators, and contract tracers; grouped as “others”. For the three tertiary hospitals (OKomfo Anokye Teaching Hospital, Greater Accra Regional Hospital, and Tamale Teaching Hospital) sampled for the study, a non-probability sampling design is a form of purposive sampling technique was adopted by the researchers for this study. Non-probability sampling was adopted to select the three tertiary hospitals as a case and Ghana to be specific as the study location. Hammarberg et al. (2016) and Wiśniowski et al. (2020) define purposive sampling as an approach to identify samples based on knowledge about the population, the designated hospitals, and the purpose of this study. The criteria(s) of the sample of the three hospitals are based on the functions and the designation of those hospitals as referral centers for the “fight” against the COVID-19 pandemic in Ghana. Respondents were from the OKomfo Anokye Teaching Hospital (35.5%; Kumasi), Greater Accra Regional Hospital (32.9%; Ridge), and Tamale Teaching Hospital (31.6%), respectively. Participants were aged 21-50 years.

Recruitment and Procedure

Participants were recruited through an online COVID-19 WhatsApp group of frontline workers from the three selected hospitals. The administrators of each group were contacted first to explain the objective and scope of the study to seek their consent and approval to use their platforms to collect the data. Upon approval, members of each group were briefed by the administrators and objectives of the study. The survey forms were shared on the WhatsApp groups of the sampled hospitals. The data collection instrument was designed with the Microsoft Forms Survey tool and the link to the data collection tool was shared on each group’s page for the volunteers to complete. Some members volunteered to participate in the study. The respondents were assured of their anonymity and the data collected were meant for only academic purposes.

Techniques and Instruments for Data Collection

A Microsoft Forms Survey tool was employed to design the data-gathering instrument. The survey questions enabled the researchers to probe further, understand, and explore respondents’ contributions. The data-gathering instrument was made up of six sections. The first section covered the demographic characteristics of respondents (age, sex, location of hospital, years of work or experience, academic, and professional qualifications). We then focused on awareness and usage of DMTs and apps among respondents. The remaining sub-sections are made up of perceived usefulness, specific use of DMTs, usage determinants of DMTs, and limitations of DMTs usage among frontline health workers.

Validity and Reliability

To ensure the meticulousness and integrity of the study, and consequently guarantee the credibility of the research findings, various steps were undertaken to improve the reliability of this particular study (Creswell, 2016; Patton, 2021). Firstly, the data-collection tool was pre-tested with a sample of 75 participants to assess the validity and reliability of the instruments from Sunyani Regional Hospital in the Bono region since we did not know the prevalence rate of usage of DMTs in COVID-19 pandemic control and management. According to Perneger et al. (2015), if the prevalence rate is not known, a default sample size of 30 and above participants is recommended.

Data Analysis

Pie charts, mean, standard deviation, and Cronbach's alpha coefficient were mostly used to carry out our analysis. The data analysis and presentation of findings of the study by testing the suggested research model through logistic regression. It also contains the descriptive statistics of the demographics and the constructs. Logistic regression plays a very vital role both in classification as well as model building. In most scenarios, it may be difficult for someone to directly assess the responses in a deterministic manner. So, there is the need to introduce a likelihood/probability concept into that. In this way, the logistic regression comes into play a very vital role where the dependent variable normally is categorical, maybe two or more than two. To address the two-category dependent variable problem a binomial logistic regression was adopted.

Measures

The instrument consisted of 10 items identified to evaluate frontline health workers' actual knowledge relating to DMT's adopted health practice. Out of the ten-key traditional variables defined by Davies (1989), three variables; *awareness, specific use,* and *perceived usefulness* were determined by this study. The three measurement variables and the five-point Likert scale used are, as follows.

Awareness

The instrument for the measurement of the level of awareness, the researchers adopted the five dimensions of measurement proposed by (Kim et al., 2006; Sarrab et al., 2015; Walton et al., 2005), which include; *NA=not aware, SA=somewhat aware, NS=not sure, A=aware,* and *VA=very aware.*

Specific use of DMTs, usage determinants of DMTs, types of DMTs, and limitations

The researchers adopted a five-point Likert scale (*1=strongly disagree, 2=somewhat disagree, 3=neither disagree nor agree, 4=somewhat agree,* and *5=strongly agree*) to measure the three variables of specific use, types of DMTs, and limitations.

Perceived usefulness

This study conceptualized the question of perceived usefulness in the following distinct measures. Seeking information; perceived usefulness: entrainment/recreation; perceived usefulness: building social relationships; self-efficiency influencer; the gratification of DMTs uses. For this study, each of the dimensions is investigated from the perspective of DMTs applied in response COVID-19 pandemic. The research items, therefore, centered basically on how DMTs benefit frontline health workers. Frontline health workers perceived usefulness of the DMTs is anchored on what these devices and technologies can offer them.

RESULTS AND FINDINGS

RQ 1: The Level of Awareness and Usage of DMTs in Response to COVID-19

The instrument for the measurement of the level of awareness of DMTs, the researchers adopted the five dimensions of measurement proposed by (Kim et al., 2006; Sarrab et al., 2015; Walton et al., 2005), which include; *NA=not aware, SA=somewhat aware, NS=not sure, A=aware, VA=very aware*. The instrument consisted of 10 items identified to evaluate frontline health workers' actual knowledge relating to DMTs adopted health practice.

The results suggest that 567 of the respondents responded *VA=very aware* to their awareness of DMTs. 280 out of 1,126 respondents responded *A=aware*, 123 indicated they were *SA=somewhat aware* of DMTs. Other responses are, *NA=not aware* 92, while 64 reported as *NS=not sure*. A descriptive statistic was conducted on these responses to ascertain the level of awareness. The average responses are (M=1.25) and (SD=0.43), which implies that average, respondents of this study have a higher level of awareness of DMTs.

Our results suggest that the majority of the respondents use DMTs. This was evident by 870 of the respondents who responded they were duly aware of DMTs in response to COVID-19. Only 256 out of 1,126

Table 1. Descriptive statistics for specific DMTs usage

Item	Specific DMTs usage	Mean	SD
1	Case location and contact tracing during the COVID-19 outbreak	2.83	1.406
2	Checking symptoms	3.44	1.435
3	Monitoring quarantine compliance by infected patients	3.66	1.523
4	Sensitization campaigns and education of infected patients	2.32	1.502
5	Follow up on affected patients at hospitals and homes	4.09	2.627
6	Education and training during the COVID-19 outbreak	3.37	1.546
7	Monitoring COVID-19 patients during the COVID-19 outbreak	3.71	1.559
Overall		3.35	1.657

Table 2. Descriptive statistics of perceived usefulness of DMTs

Item	Perceived usefulness	Mean	SD
1	Help in monitoring adherence to treatment	2.88	1.225
2	Convenience and easy to use for healthcare delivery	2.96	1.461
3	Help improve COVID-19 post-treatment	3.92	1.342
4	Support in medical decision-making	3.08	1.103
5	Facilitate patient access to health information during the COVID-19 outbreak	3.33	1.752
6	Assist in collecting more accurate clinical history	3.84	1.502
Overall		3.34	1.398

respondents responded *NA=not aware*, and *NS=not sure* which implies they do not use. To ascertain the degree of usage descriptive statistics were conducted, with the following outcomes; (M=1.30) and (SD=0.46), this implies that on average, the degree of DMTs usage by respondents is high. Our study revealed that even though frontline health workers were aware of these DMTs, not all of them were necessarily users. This is evident in the decreased responses of awareness to the usage of DMTs (n=870) compared to those who responded *NA=not aware* and *NS=not sure* to awareness of these DMTs (n=256).

RQ 2: The Specific Usage of DMTs for Health Care Delivery During COVID-19

The highest average score for item "*follow up on affected patients at hospitals and homes*" (M=4.09; SD=2.963) and least item score is "*sensitization campaigns and education of infected patients"* (M=2.32; SD=1.50). All the indicators on uses had an average score higher than 3.30, which was beyond the median of 3. This signifies that the degree of usage of DMTs among the respondents is high (**Table 1**).

RQ 3: Perceived Usefulness of DMTs in Response to COVID-19 Outbreak

Taken together, the item *"digital mobile technologies and apps help in monitoring treatment adherence"* had the highest average score (M=3.92; SD=1.342) while the least item score came from "*digital mobile technologies and apps can assist in collecting more accurate clinical history"* (M=2.88; SD=1.225). All the indicators on the perceived usefulness of DMTs in response to the COVID-19 outbreak had an average score higher than 3.30 which was beyond the median of 3. This signifies that the perceived usefulness of DMTs among the respondents is high (**Table 2**).

RQ 4: Usage Determinants of DMTs in Response to the COVID-19 Outbreak Among Healthcare Workers

In this study, the independent variables for the model to be developed are; *age, sex, profession, hospital of work, experience, awareness of DMTs, specific use of DMTs, perceived usefulness of DMTs,* and *limitation of DMTs usage*. The dependent variable is the decision to use DMTs.

Classification for likelihood of usage or non-usage

The binary logistic regression model seeks to predict the likelihood of respondents using or not using DMTs. The outcome of the model classification suggests a prediction of the likelihood not to use DMTS as the dependent and it's shown in the generalized model equation and **Table 3**. Therefore, the generalized model equation is given as: logit (non-usage)=$\ln(\frac{p}{1-p})$ =a+β_1*age+β_2*gender+β_3*profession+β_4*hospital+ β_5*experience+β_6*awareness+β_7*specific use+β_8*usefulness+β_9*limitation.

Table 3. Model summary

Step	-2 log-likelihood	Cox & Snell R square	Nagelkerke R square
	424.037	0.573	0.811

Table 4. Model accuracy

Observed			Predicted		
			Usage		Percentage correct
			Yes	No	
Step 1	Usage	Yes	783	1	99.9
		No	61	281	82.2
	Overall percentage				94.5

There is the need to figure out all the regression coefficients and predict whether a typical case is likely not to use DMTS. The summary of the logistic regression is presented in the tables that follow.

The Nagelkerke *R square value of 0.811* depicts that the model is a good fit explaining about 81% of the variability in the dependent variable "non-usage of DMTs." To test the goodness of fit of the model, we use Hosmer and Lemeshow test (HL test quite similar to the Chi-square test), which can be seen in **Table 3**.

It can be seen from **Table 4** that the model accuracy (correct predictions) is about 94.5%, which can be treated to be satisfactory. The remaining 5.5% is not explained by this model.

Model equation summary

The model equation takes into account all categorical independent variables and also displays key parameters as described below:

B (unstandardized Beta): These are the coefficients for the regression equation.

S.E.: The **standard error tells** you how accurate the mean of any given sample from that population is likely to be compared to the true population mean. When the **standard error** increases, i.e., the means are more spread out, it becomes more likely that any given mean is an inaccurate representation of the true population means.

Sig: Represent the computed *p-value,* which is used as a measure of statistical significance of an attribute of this study. *p-values greater than 0.05* suggest that a particular independent variable of interest has an insignificant effect on the dependent variable. *p-values less than 0.05* suggest that a particular independent variable of interest has a significant effect on the dependent variable.

Exp (B): Also known as the odds ratio. It quantifies the strength of the association between two events, A and B. Exp (B) greater than 1.0 suggests more likelihood while Exp (B) less than 1.0 suggests less likelihood. The analysis of the variables in the logistic regression model shows that with exception of years' experience of the frontline health workers, all of the odd's rations are not significant, and hence, the rest of the variables cannot be interpreted (**Table 5**).

RQ 5: Limitations to the Usage of DMTs among Frontline Health Workers in Response to COVID-19

The highest average score, was for the items *"Internet service is unreliable in Ghana, limiting us from using DMTs in healthcare services delivery"* (M=3.99; SD=1.311) while the least item score came from "*inadequate rigor required to make them reliable and viable healthcare tools"* (M=2.76; SD=1.522). All the indicators on limitations of DMTs had an average score higher than 3.60 which was beyond the median of 3. This signifies that there is a high limitation of DMTs usage among the respondents (**Table 6**).

DISCUSSION

The COVID-19 pandemic as reported by the WHO (2020a) indicated that the pandemic has unleashed lasting and profound challenges to the global community and affected every facet of our human endeavors. Public health systems and frontline health workers within developing countries are confronted with various structural challenges. Paramount among these is the direct burden on frontline health workers, resulting in

Table 5. Model equation

		B	S.E.	df	Sig.	Exp(B)
Step 1	**Age**			2	0.224	
	Age (1)	0.129	1.094	1	0.906	1.137
	Age (2)	-1.650	0.983	1	0.093	0.192
	Gender (1)	-0.122	0.388	1	0.753	0.885
	Profession			4	0.102	
	Profession (1)	0.572	1.496	1	0.702	1.773
	Profession (2)	1.789	1.252	1	0.153	5.985
	Profession (3)	-0.286	1.415	1	0.840	0.752
	Profession (4)	1.540	1.668	1	0.356	4.666
	Hospital			2	0.973	
	Hospital (1)	0.098	0.453	1	0.734	1.090
	Hospital (2)	0.117	0.588	1	0.842	1.124
	Hospital (3)	0.083	0.383	1	0.828	1.087
	Experience			4	0.314	
	Experience (1)	-0.350	0.852	1	0.681	0.705
	Experience (2)	-2.305	1.070	1	0.031	0.100
	Experience (3)	-2.013	1.135	1	0.076	0.134
	Experience (4)	-1.483	1.157	1	0.200	0.227
	Awareness (1)	-23.975	2343.357	1	0.992	0.000
	Specific use	0.209	0.175	1	0.231	1.233
	Usefulness	0.350	0.491	1	0.477	1.418
	Limitation	0.184	0.336	1	0.584	1.202
	Constant	19.875	2343.358	1	0.993	428028401.908

Table 6. Descriptive statistics for limitations of DMTs the usage among frontline health workers in response to COVID-19

Item	Limitations	Mean	SD
1	Inadequate rigor is required to make them reliable and viable healthcare tools	2.76	1.522
2	The safety and security of user data limit the usage of DMTs in healthcare services delivery	3.89	1.422
3	Internet service is unreliable in Ghana, limiting us from using DMTs in healthcare services delivery	3.99	1.311
4	Internet data is expensive and prevents us from using DMTs in healthcare services delivery	3.96	1.286
Overall		3.65	1.385

serious human resources, and health infrastructural challenges, in some developing countries (WHO, 2021). Per the official report of WHO as of the first week of March 2022, this pandemic has infected 125 million persons globally and claimed 6.14 million lives (WHO, 2022). According to data released by the WHO, and the Ghana service in week one of March 2022 indicated that 160,640 persons have been infected by the virus, and of these, 1,442 persons have died in Ghana (Ghana Health Service, 2022; WHO, 2022). A great number of health systems experience shortages of competent healthcare personnel, a factor that leads to unfavorable outcomes for many patients as a result of the inadequate use of technology in response to the COVID-19 pandemic.

The use of DMTs offers a cheaper, more accessible, and available option to frontline healthcare workers involved in the management of this pandemic (WHO, 2020a). Hence, we adopted TAM to study the adoption, utilization, and limitations faced by frontline healthcare workers involved in COVID-19 management in Ghana. The present study found that 75.1 % (n=846 out of 1,126) of frontline healthcare workers comprising nurses, biomedical scientists (laboratory technicians), medical doctors, physician assistants, cleaners, monitoring and evaluation officers, hospital administrators, and COVID-19 contact tracers were aware of DMTs, adopted and used them in response to the COVID-19 pandemic (**Table 1**). However, 69.6 % (n=784 out of 846) of those who were aware of the DMTs employed them in their daily operations in their fight against the COVID-19 pandemic (**Table 2**).

One of the important strategies to "flatten the curve" of the COVID-19 infection was rigorous contact tracing (Owusu, 2020). This approach exposes frontline health workers to higher risks of COVID-19 (WHO, 2020b). To overcome this limitation, more than 25 countries worldwide including Ghana adopted DMTs in aggressive nationwide contact tracing. The present study reveals several uses of DMTs in the fight against COVID-19, including following up on infected persons in hospitals and homes, monitoring COVID-19 patients during the outbreak, monitoring quarantine compliance by infected patients, and checking symptoms after detection (**Table 2**). These partly agree with the findings of (Budd et al., 2020; Horgan et al., 2020; Scott et al., 2020; Whitelaw et al., 2020).

The present study embodies the theoretical, practical, and policy implications of the research findings.

First, the study poses implications for theory. Undoubtedly, this study contributes to research on TAM and COVID-19 management in developing countries like Ghana (West Africa) by demonstrating the usefulness and limitations that serve as impediments to wide usage among frontline health workers in Ghana. Our findings support the emerging theories of TAM and are consistent with reports by Safi et al. (2019) who suggested earlier theoretical models of technology acceptance seemed to be inefficient. Davies (1989) established a 10-factor model, a move aimed at developing an integrative approach that unified 10 aspects to determine user acceptance based on affordability, accessibility, usability, value, experience, emotion, confidence, experience, social support, and technical support features of innovations. The approval and acceptance of new technologies may also significantly minimize errors and related costs and key impediments (factors) as crucial to ensuring the acceptance and adoption of new technologies.

We found that awareness of DMTs alone contributes to greatly the usage of common DMTs in response to the COVID-19 outbreak in Ghana. Technology adoption is dependent on awareness which increases rapidly among operational telehealth teams (Clippers, 2020). This important factor is missing in the earlier TAM (Davies, 1989). Also, none of these variables such as age, sex, profession, perceived usefulness, limitations, specialty, and location of the hospital was significant in the logistic regression model. Whereas experience in healthcare practice occasioned a 0.23-1.50 % reduction in usage of DMTs among the frontline health workers. Therefore, we recommend future studies incorporate these variables in their models to evaluate wider contributing factors to technology adoption and usage.

Secondly, the study poses implications for practice. The use of digital technology in response to COVID-19 ushered in a promising new milestone in the execution of mass global public health response and interventions (Owusu, 2020). Our study documents the uses of the DMTs in response to COVID-19 in three tertiary hospitals in Ghana which could be useful for other regions and countries in the fight against COVID-19 and future pandemics. These technologies minimize the burden of patients' continuous self-reporting and circumvent recall bias from infected persons. Additionally, DMTs can facilitate pandemic strategic response in ways that are difficult to achieve manually (Zhu et al., 2020). Also, the pandemic has accelerated the rate at which artificial intelligence technologies are being integrated into healthcare service delivery to decrease exposure among frontline healthcare and non-healthcare workers (Wittbold et al., 2020). Therefore, regular training on the use of DMTs is highly recommended.

Thirdly, the study poses policy implications for the future adoption of DMTs. Our findings reveal that usage of DMTs (**Table 6**) among frontline health workers exposes several challenges that need urgent attention from the government of Ghana, the Ministry of Communications, and telecommunication companies to make data services affordable and reliable to harness the useful benefits in the fight against COVID-19. Public health management globally has long been underfunded compared to other areas of health (Marmot et al., 2020). Therefore, long-term changes require deliberate investments in national and international digital centers of excellence with the needed balance of partners and pre-agreed access to digital technologies with a substantial investment in workforce education, skills, and facilities to derive the full benefits to the country (Marmot et al., 2020). These regulatory adjustments could mitigate cyber-attacks and as protocols for smart response to any vulnerabilities uncovered in usage (Gerke et al., 2020).

CONCLUSION

Findings from this study indicate that digital health innovations have the potential to benefit the frontline health worker and civilian populations, which could ensure accessibility, security, reliability, and sustainability of public health response and interventions. To reap the full effects of digital mobile technologies, Ghana and other developing countries may need to formulate clearer guidelines to ensure transparency and security in their adoption and usage among frontline healthcare workers in the post-COVID-19 era. Also, the TAM employed in this study is relevant for studying technology adoption, utilization, and challenges in developing countries. We recommend health authorities and governments in developing countries incorporate DMTs in their contemporary healthcare systems, especially in public health emergency preparedness. This study has demonstrated that DMTs have marked potential for improving the quality of health care services delivery in developing countries, if stakeholders, policymakers, and other duty bearers can develop robust, cheap, and reliable data infrastructure and supports the usage of these innovations.

Limitations and Future Work

This study was undertaken at three tertiary hospitals in Ghana, Tamale Teaching Hospital, Komfo Anokye Teaching Hospital, and Greater Accra Regional Hospital (Ridge). Future studies on public health crises such as COVID-19 could be investigated on a national or continental scale to include more health facilities and frontline workers. It is important to note that the findings can, therefore, not be overgeneralized. However, the limitations may not impact the overall technical implications of the findings of the study. The implications of this study in response to the COVID-19 pandemic and the popular adoption and usage of DMTs among healthcare workers in Ghana have far-reaching benefits and lessons for developing countries, especially in Africa.

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