The effectiveness of COVID-19 surveillance applications in Uganda:: assessment of a medical rapid response system

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Abstract

Different Information Communication Technologies (ICTs) health-based innovations such as cloud computing, web and mobile surveillance applications were used by proactive governments to fight COVID-19. Contact tracing mobile applications were used by more than 100 countries. However, the extent to which these surveillance applications have been used to track Covid-19 in Uganda is not clear. This study aimed to establish the use of COVID-19 surveillance applications in Uganda. This was a purely qualitative study. Health practitioners managing these surveillance applications were interviewed from Kampala City, Mukono and Wakiso districts of Uganda. The assessment of the COVID-19 surveillance applications underscores the relevance of health-based ICTS. The surveillance applications provided accurate, authoritative and timely data. However, there were false alerts as result of inaccurate data supplied by the applications. The study recommends increased facilitation of the surveillance officers, continuous training of surveillance teams and integration of the applications for the management of other non-communicable diseases.

Keywords: *Surveillance applications, health based ICTs, COVID-19, Uganda*

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INTRODUCTION

The Corona Virus Disease 2019 (COVID-19) challenged almost every country in the world, most especially in terms of breaking the capacities of health systems and melting down economies (Assoumou-Ella, 2021). In Sub Saharan Africa, it was worse as it found the sub region already grappling with other diseases like HIV/Aids, Ebola, Tuberculosis and other non-communicable diseases (Goswami et al., 2021). This crisis sparked off a world debate on the best way to manage pandemics and discussions on the same are still ongoing on the superlative therapy options, diagnostics and its appropriate control through the use of drugs, vaccines and antibodies (Pavelić et al., 2021). While there have been a number of medical interventions in the area of testing, therapy and vaccination, there have also been a number of social-humanistic non-medical approaches that have been devised (World Health Organisation, 2020). Whereas some governments have attempted to proactively provide socio-humanistic non-medical approaches through building digital infrastructure and introducing e-government systems to ease the fight against COVID-19, other governments have relied on lockdowns to control the fast spread of the deadly virus. Though lockdown effectively curtailed the infection rates in Uganda, it negatively affected the economic and social wellbeing of society (Buwule et al., 2021).

Action against the spread of COVID-19 in Uganda was largely left to the central, regional governments and community leaders. These leaders mostly depend on virologists to collect and interpret all kinds of data on the pandemic. Smart leaders attempted to work with digital industries and think tanks which rapidly digitalized the management of the COVID-19 data (Karak et al., 2020). Some of such digital health-based innovations included; COVID-19 symptom tracker, smart thermometer, trace contacts together, use of robots to check temperature, sanitize and dispense goods and services among others (Sumartojo & Lugli, 2022). In Uganda, the Ministry of Health(MoH) employed the CovidTracer application and the Ministry of Health Call the Clinic (MoHCTC) application in the surveillance of COVID-19 (Mwanzia et al., 2021). This approach is largely driven by high tech innovations and has allowed the integration of day-to-day devices such as smartphones which any average community member can use.

Covid-19 surveillance applications

According to extant literature, there are basically three types of Covid-19 surveillance applications used around the world. These are routine surveillance, laboratory surveillance and help lines (Ibrahim, 2020). COVID-19 routine surveillance applications are comprehensive and report COVID-19 cases, as well as aggregate the data on a daily, weekly or monthly basis. Some may also report COVID-19 symptoms of suspected cases, contacts and their movements or isolation statuses. The laboratory and hospital-based surveillance applications mainly report and record the test results of the suspected COVID-19 patients and victims. The final category is mainly alerting or messaging applications that present themselves in form of help-lines, hot lines, chatting or messaging platforms. The messaging applications are participatory. They require the user to have some electronic and digital skills. They have also been found to be relatively cost-effective. All the three types of COVID-19 surveillance applications are prompt health based ICT surveillance and detection applications for infected patients (Adenyi et al., 2020). The health sector makes an effort to enhance mobile monitoring technologies to respond promptly to health risks, disease prediction and emergency response. These mobile applications heavily rely on an expanded electronic access to using applications for data and information. The process of collecting this ensures that the data collected is safe and secure. Key factors to observe while assessing the potential of health-based surveillance applications may include information security of the biometric systems, distinctiveness of the data, permanency, universality, capability to measure the data accuracy, resource effectiveness, invulnerable and acceptability with the users (Khan et al., 2021).

Smart healthcare systems require recording, transmitting and processing large volumes of multimodal medical data generated from different types of sensors and medical devices, which is challenging and may turn some of the remote health monitoring applications impractical. To ensure that the health sector has a smart and a rapid response medical system that can monitor epidemics and health risk, there is a need to assess the effectiveness of the surveillance applications. According to the reviewed literature, there are 19 key parameters that can be used to determine whether the health based ICT surveillance application is effective or not and these are: user acceptance, ease of use and access, elasticity of the network, mobility and portability, energy conservation, cost saving, accuracy, reliability, speed, data visualization, use of artificial intelligence, big data, machine learning, block chain, sharing of resources and integration with other social media platforms, protection of personal data and privacy, transparency, information security and capability of archiving and backing up of data (Adenyi et al., 2020; Ahmad et al., 2021; De Lusignan et al., 2020; Eck & Hatz, 2020; Hussein et al., 2020; Ibrahim, 2020; Khan et al., 2021; Kostkova et al., 2021; Marinaccio et al., 2020; Whitelaw et al., 2020; Zhang et al., 2020). The top five parameters highlighted by most authors were: accuracy of the data generated by the application, access and ease of use of the application, speed of the processing time, efficiency of the artificial intelligence and the security of the information. In Ibrahim's (2020) study on the same, he reiterates that timeliness and accuracy are very essential when assessing the effectiveness of a COVID-19 surveillance application. These were the same five parameters this study emphasized among the 19. This study aimed to establish the level of application and effectiveness of the COVID-19 surveillance applications in community health during the COVID-19 pandemic in Uganda to understand how the applications supported the rapid response medical system of MoH. It was guided by four objectives and these were:

a) To identify surveillance applications used to mitigate the COVID-19 pandemic in Uganda

b) To assess the efficacy of the COVID-19 surveillance applications in the community

c) To examine the adoption and integration of the COVID-19 surveillance applications in the community.

d) To establish the drivers and barriers of adopting the COVID-19 surveillance applications in Uganda.

Methodology

This study used a qualitative research approach and most of the collected data was mainly in the form of audio, text and images. Qualitative data provides detailed and explicit understanding of the research topic as it requires the respondents to observe, accurately analyze and keenly describe the meaning, patterns of the phenomenon (Creswell & Clark, 2011; Silverman, 2020).

Semi-structured interviews were conducted with the district and sub-district COVID-19 surveillance officers which included health centre in-charges (doctors and clinical officers), health inspectors and educators, nurses, medical records assistants, laboratory technicians and members of the Village Health Teams (VHTs) who interacted with the COVID-19 surveillance applications. These health workers were purposively sampled from Kampala City, Mukono and Wakiso districts. Kampala is a city and therefore largely urban while Mukono and Wakiso districts are both semi-urban and rural. These three areas were chosen since they are largely urban areas with a higher penetration and use of ICTs compared to other districts in Uganda. Interviews were used because they enabled the researchers to obtain information on the opinions, meanings, perceptions, construct reality, understanding and feelings of participants through dialogue (Matthews & Ross, 2010; Punch, 2014). This study also adopted purposive sampling as a method employed in qualitative research to identify and select in-depth information to validate the qualitative findings (Tashakkori & Teddilie, 2010). Purposive sampling entails identifying and selecting groups of knowledgeable individuals who can be used for interview purposes relating to the phenomena under investigation (Creswell & Clark, 2011; Palinkas et al., 2015).

Both open and closed ended questions were asked to obtain further insights into the phenomenon. For open ended questions, the researchers would probe further to seek clarity for incomplete and unclear answers (Grecu & Ciobanica, 2014). The interview process encompassed comprehensively asking relevant questions, listening, and paying attention to and recording respondents' responses in a semi-structured arrangement. The researchers would schedule an appointment based on the availability of participants prior to the interview date. The interviews were both face-to-face and electronically through telephone calls. The face to face interviews ensured adherence to strict COVID-19 protocols of sanitizing, wearing face masks and maintaining social distance. Each interview session lasted approximately 20 minutes. Eighteen (18) Interviews were recorded from the districts of Mukono (five participants), Kampala (six participants) and Wakiso (five participants) until the study reached the saturation point of the exact details and views of participants relating to the topic being researched. Small samples and participants are generally selected to provide in-depth description of their knowledge and experience, thereby supplying rich data to enhance the researchers' understanding (Alase, 2017). The recorded interviews were later transcribed, and coded using Atlas.ti version 9.

This research adopted a thematic data analysis process to analyze the qualitative data. The transcripts from the recordings were read and re-read, key notes were taken, the researchers named and defined the themes, categorized themes, generated codes, attached the codes to themes, interpreted the meaning of themes, and reported the findings (Silverman, 2020). The thematic analysis enabled the researcher to formulate new ideas and concepts emanating from the qualitative findings (Maguire & Dalahunt, 2017). The researchers were cautious of the study's ethical concerns. This study was conducted in strict compliance with Uganda Christian University Local Research Ethical Committee and the Uganda National Council of Science and Technology's Policy on Research Ethics which clearly stipulates issues of anonymity, confidentiality, respect of privacy and informed consent among others.

Research Findings and Discussions

Of the 18 Covid-19 surveillance officers who participated in the study, six were from Kampala City, seven were from Wakiso District, while five were from Mukono District. Below is a presentation and discussion of the findings of this study.

COVID-19 surveillance applications in Uganda

From the data collected, there were a number of surveillance strategies used in Uganda to control the spread of COVID-19. The COVID-19 surveillance strategies included both ICT-based and non-ICT based strategies. The ICT-based surveillance strategies included the use of mobile phones to make calls, COVID-19 toll-free hotline, mobile phone applications (i.e. National Covi-19 Vaccination Portal-Epivac, Home Based Care and Response (HBCR), Smart Paper Technology (SPT), Open Data Kit (ODK), Electronic Laboratory Investigation Form (ELIF), Integrated Diseases Surveillance and Response (IDSR) MoH CovidTraceralso known as MTrack), use of non-contact thermometers, and the COVID-19 Lab manager. The non-ICT based surveillance strategies included the active case search, use of VHTs, health facility based surveillance, and community based surveillance. Some of these applications have been illustrated in Fig. 1, 2 and 3 below. One respondent from Kampala was happy to note that: "*In Kampala, people complied with the Standard Operating Procedures (SOPs) of COVID-19 such as, hand washing, social distancing and wearing masks".* The implementation of the SOPs including the use of non-contact thermometer was an innovative means of managing the spread for COVID-19 in some health facilities in the study areas

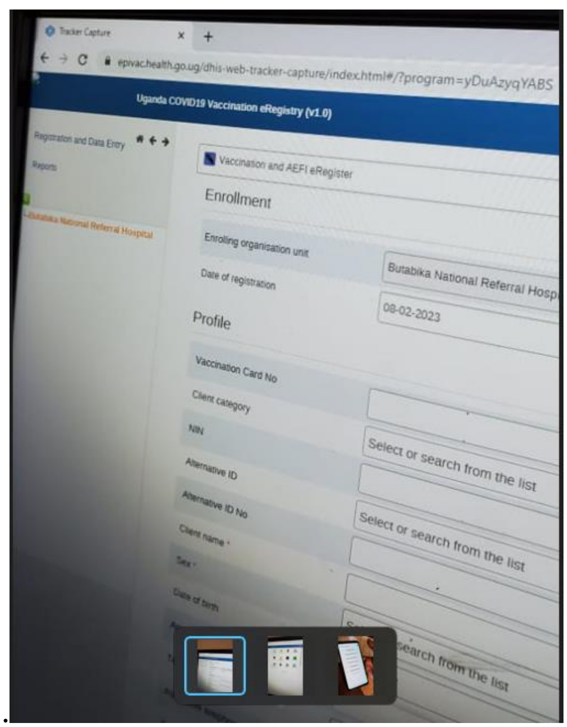

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Fig. 1. Screen display of the National COVID-19 vaccination portal

The most popular ICT-based surveillance applications according to this study were: IDSR Application (This was a home based-care application developed by the infectious Diseases Institute to monitor COVID-19 patients who were sent to their homes to manage the treatment of COVID-19), MoH CovidTracer (for contact tracing), Epivac (for managing COVID-19 vaccination), ELIF, HBCR developed by Infectious Diseases Institute and finally, a WhatsApp group for COVID-19 surveillance officers. When the respondents were asked if they had used any of the stated COVID-19 surveillance applications, all participants from Kampala, Mukono and Wakiso except one replied in the affirmative. The highly used COVID-19 surveillance applications were phone calls (10 responses), Contact Tracing (7 responses), Ministry of Heath Tracker (3 responses), Epivac (3 responses) and ELIF (3 responses). One health inspector from Kampala stated that:

> "*The MoH CovidTracer is like a community based surveillance system. It works like a health facility based surveillance mechanism that can do both active case search and contact tracing.*"

It should also be noted that whereas surveillance applications were used in Kampala City and Wakiso district, Mukono district mainly relied on the use of phone calls to the Ministry of health hotlines. One member of the Village Health Team from Mukono retorted that: "*Before, we used to call the in-charge of the Health Centre until they gave us a hot line of 6767.*" Other respondents from Mukono also confirmed that they used to hear of COVID-19 applications in Kampala but they did not use them. They just used to call the in charges to send ambulances whenever they would get an alert or a suspected COVID-19 patient.

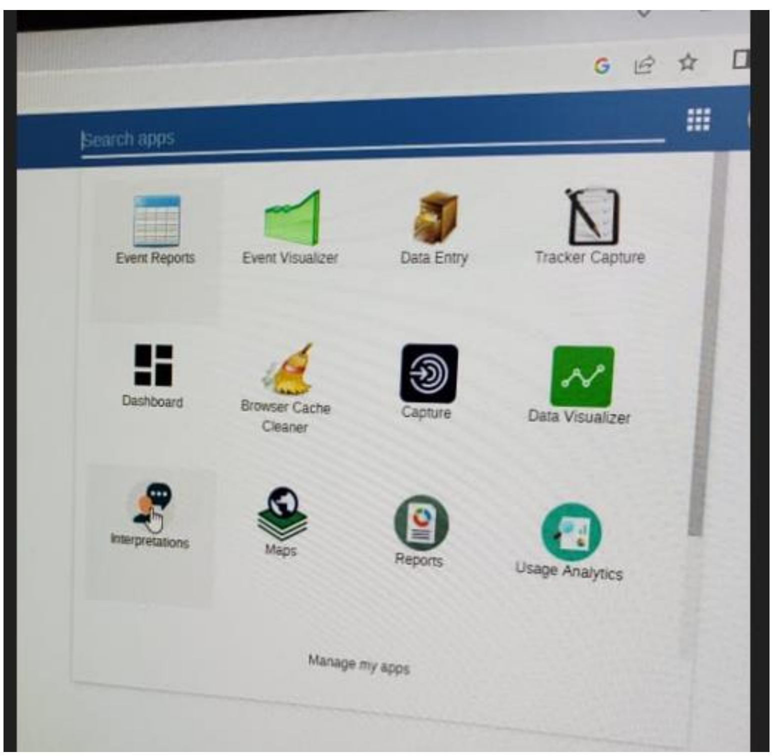

Fig. 2 MoH CovidTracer interface

The Norwegian Institute of Public Health (NIPH) launched a COVID-19 surveillance application called *Smittestopp* ("infection stop") to collect information on the movements of people who had contacted COVID-19 patients (Eck & Hatz, 2020). This application was described by Amnesty International (2020) as one of the most invasive COVID-19 contact tracing application in the world. In Uganda, there was a similar contact tracing application known as MoH CovidTracer but only a few of the respondents were bothered about the application invading the suspected COVID-19 contact's private lives or movements.

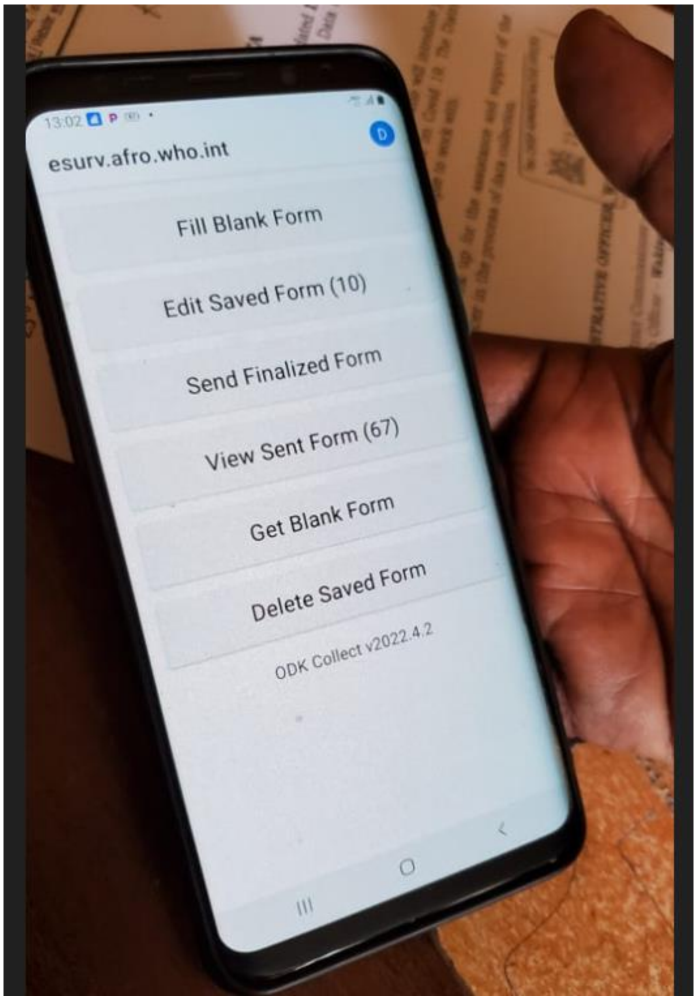

Fig 3. Drop down menu for the ODK surveillance application

Basing on the views of the respondents in this study, it can be clearly seen that the COVID-19 pandemic triggered the development of an array of surveillance applications which, to a great extent controlled its spread. These different surveillance applications created a link between the data generated from social groups and the MoH departments and agencies. Governments across the globe focused on containing and mitigating the pandemic with the help of these applications. Countries that maintained low COVID-19 per-capita mortality rates managed to have this success by using surveillance applications that included testing, contact tracing, and strict quarantine (Whitelaw et al., 2020). For example, members of the community would cooperate with the government by using the COVID19 contract-tracing on their smartphone or mobile device to alert the authorities. Others would just even use a phone or call the hot line informing them of a suspected COVID-19 victim and the concerned health officials would immediately swing into action (Newell, 2021).

The COVID-19 pandemic has led to an exponential increase in the quantity of data generated by surveillance applications. There is need now for novel big data systems that can harvest, analyze and interpret this surveillance data (Kostkova et al., 2021). It remains to be seen whether these interventions will be sustained most especially in a context of a developing economy like Uganda. Also, the fact that some members of the community abused the applications by feeding them with false alarms should not be forgotten. There were also a few respondents who were concerned about the applications invading their privacy. Maybe decentralizing the personal data storage of the surveillance applications as opposed to using a centralized data storage may help increase the faith of the public in how these applications manage their personal data (Zhang et al., 2020).

Participants' experience with the COVID-19 surveillance innovations

Participants had mixed descriptions on their experience in using the surveillance applications. They noted that the applications were effective as a reporting tool on COVID-19 and supported the flow of information from the communities, through the village health teams, to the district surveillance teams and the MoH. They were easily accessible by use of mobile phones and compatible with the manual register provided by the MoH. Interestingly, participants noted that the applications were user friendly; could be used for Rapid Diagnostics and Testing (RDT); and provided authoritative information. A female medical records assistant from Kampala informed the researchers that:

> *"Contact tracing and active search has helped in easing the contacts of the COVID-19 victims. We test them and those who are positive are referred for treatment as early as possible. Health facility based surveillance has enabled counselling of the victims. Information flows from a remote health facility. Good enough the staff are well mentored on how to handle. They also report cases referred to the private health facilities. The communication starts from the community to the health centre at the Division, to the City and finally to MoH."*

One of the public health assistants from Wakiso District apparently stated that "Epivac *is effective but it is not the case with SPT. After scanning, SPT is supposed to synchronize the client's details with Epivac but many times we find that the data uploaded using SPT is incomplete.* Although there were several positive reports, the use of these applications was not perfect throughout. A couple of participants decried the lack of data and poor internet connectivity as disruptive when using the applications. In addition, it was challenging to use the applications due to limited training provided. As a result, the applications would record inaccurate and incomplete data. Below is an excerpt from a laboratory technician from Kampala:

> *"At the beginning it was challenging. We would send messages and they would jam but they have tried to rectify the network and connectivity issues. It was slow but they worked on it. ELIF is a reporting tool. After doing a test and the results are positive, we enter the results in ELIF and also in the manual register."*

One health assistant from Mukono explained in detail how the surveillance was done using phones:

> *"After MoH receiving the alert, they would communicate to the sub county supervisor to go to the scene of the suspected COVID-19 victim. Sometimes the community members would call me and then I would inform the in-charge who would mobilize a team to go to the scene of the suspected COVID-19 victim. VHTs would be sent to the suspected victims to continue counselling them on how to comply with the home based management of COVID-19. The VHTs would go further and speak to the affected community members on how to guard themselves from the suspected COVID-19 cases"*

Most of the research participants indicated that the applications they had used were effective. However, there was a higher preference for Epivac and the non-contact thermometer. Interestingly, participants highlighted that community based surveillance and the vigilance of the VHTs was very critical for the successful use of the applications since they provided leads to the COVID-19 victims. A male nurse from Kampala had this to say:

> *"Community surveillance with the help of the applications is interlinked and works as a chain. If one link is broken, it affects the whole surveillance process. Community based surveillance is the most preferred with the enhancement of the applications and it also equally depends a lot on the vigilance of the VHTs.*

In Scotland, Mark et al., (2021) attempted to understand the community vigilance of participants experience while using the surveillance applications. They noted that innovating when facing a challenge such as a pandemic can significantly compel members of the public to actively involve themselves in the innovation and the use of an application, especially if it is an open platform web-based surveillance application. In a similar way, the COVID-19 pandemic enabled global digital connectedness and collaboration which resulted into the expedition of the scientific process, rapid consolidation of global outbreak data, statistics, and experimentation with novel partnerships (Bernardo et al., 2021). However this rushed involvement in the use of the applications by the community may raise profound concerns such as invasion of personal privacy and data protection. Government or the authorities have to explore regulatory and technical measures needed to protect privacy, data protection and other ethical issues that might raise the questions from the community (Newlands et al., 2020).

Efficacy of the COVID-19 surveillance applications in the community

The participants explained that the applications were highly effective in that they were easy to use, convenient, and authoritative. They provided accurate and timely information, reliable data, and enhanced the confidentiality of the information. The use of the applications made COVID-19 reporting easier as they were compatible with the manual register and other health management information systems from MoH. The ease of use was attributed to their integration with the mobile phones.

The research participants however, cautioned that, the accuracy of the information provided was dependent on the training of the surveillance officers, and the correctness and completeness of the data entered.

The alerts generated by the applications prompted quick and timely responses from the MoH and the evacuation of the COVID-19 suspects. However, not all alerts were acurate. A case in point was raised by one health inspector in Kampala who stated that: "*Accuracy is still lacking. Sometimes they would identify suspected COVID-19 patients with visible symptoms, alert the COVID-19 task team only to test and find it was false".* The participant clarified that the inaccuracy in reporting was a result of the prevalence of other diseases which present with similar symptoms as Covid-19.

According to one of the public health educators from Mukono, the community was sensitive of the information related to Covid-19:

> *"The community was very sensitive to inform us of any suspected case of COVID-19. We would immediately call the hotline though sometimes we never used to get feedback in form of calling back or texting to let us know how they were responding to our alert. The MoH would endeavor to promptly respond to our alerts. We also made sure that our alerts were accurate."*

A similar incident played out also in Wakiso as narrated by one of the respondents there:

> *"Generally the applications have been very helpful. For example, there were suspects in Kireka and Bukasa and we were not aware. The focal person for Wakiso alerted me, we took the samples, tested them and the cases were well managed. They indeed helped in controlling the spread of the pandemic."*

A related study conducted in Iran by Rahimi et al., (2021) revealed that the majority of the participants were interested in using the COVID-19 surveillance applications. The use of these applications depends on cognitive and social factors of individuals using them. There is need for policies and regulations to protect the privacy and personal data governance of the individuals who use these applications (Rahimi et al., 2021). COVID-19 surveillance applications are effective enough to manage most emergencies, reassure the citizens and also following up patients remotely. Actually surveillance applications like tele-assistance in orthodontics will have a role to play in the near future in case other pandemics break out (Maspero et al., 2020).

Nevertheless, the challenge with the use of these applications was that they were dependent on the availability and speed of the internet, proficiency in use by the surveillance officers and the positive attitudes of the community towards the use of ICTs. The limited funding and lack of data affected the use of the applications too. These hardships were not only in Uganda, overall, there has been scant regard for digital tools, which is surprising because most of these applications are operated on smartphones or mobile devices which are ubiquitous across the globe. While there were successes and failures in the efficacy of these applications, outbreak epidemiology and individual screening was substantially enhanced by the reach of these applications. (Pandit et al., 2022). It should also be recalled that some of these applications required the use of the toll free line which was fairly cost effective and did not require special devices or training when making the phone calls.

Adoption and integration of the COVID-19 surveillance applications

While the highest percentage of participants agreed that the COVID-19 surveillance applications have been embraced, a few others mentioned that they have not been well embraced. The adoption of the applications was mainly tagged to the level of awareness of the applications among the surveillance officers, trainings received, availability of resources such as internet and the user friendliness of the applications. The highest levels of difficulties in adopting these COVID-19 surveillance applications was evidenced in Mukono District. One of the senior health inspectors there stated that "*the applications have not been embraced because many of the concerned health workers didn't know them.*" Another nurse related it to the fact that they found calling the hotlines far much easier that using the applications. She confessed that "*There was nothing so complicated with calling the hotline so no one experienced challenges with that*". Elsewhere in Kampala and Wakiso, the applications were easily adopted and integrated. One of the in-charges of a health center in Kampala said in the affirmative that "*Yes, the applications required teamwork, they were also promoted by the media.*" In many other countries, surveillance applications were deployed to curb the spread of COVID-19 which led to significant inroads in terms of rapid and widespread adoption. Extant literature shows that adoption of these applications in future will be possible by incorporating security measures with the technologies that are merged with artificial intelligence and big data (Mohd Aman et al., 2021). Moreover, a study was conducted to investigate the user experience of artificial intelligence in surveillance applications and it was surprising to find out that lack of transparency by the users of the application could not negatively affect their user experience (Skjuve et al., 2019).

Drivers to the adoption of the COVID-19 surveillance applications

The most influential factors driving the adoption of the COVID-19 ICT surveillance applications in descending order included timely information, compatibility with mobile devices, training of the surveillance offices, user friendliness of the applications, commitment from the VHTs, accessibility of the applications and availability of technical support. One of the VHT members was happy with the way they were trained to use the applications and he stated thus: "*The VHTs on the ground were trained to handle the applications. We received appropriate support and timely response from the authorities.*" This is a basic indicator of a rapid response medical system. Another male nurse in Kampala opined that the key driver for adopting these applications was ease of use as he explicitly stated that "*The applications were easy to learn, they can work with most mobile devices, they save time, cost and promote a lot of team work among the surveillance officers.*" Essentially when the software developers, designers and MoH are planning for the adoption of these applications, it is very important to bear in mind these key drivers. According to Lehane (2019), there are three key factors that influence the intuitive use of surveillance applications and these are: familiar user expectations, confident interactions with the applications and leverage of prior learning.

Another respondent from Wakiso commented on the effectiveness of the WhatsApp group and how this influenced their adoption "Since *there were travel restrictions during the lock down, the WhatsApp groups were very effective in relaying information about the COVID-19 suspects.* This was intriguing to note because a related study conducted on psychologists in Australia revealed that the adoption of mobile phones, other mobile digital devices and generally the widespread digital literacy is creating new possibilities in approaching and supporting digital communication as opposed to face-to-face approaches. Though the use of digital technologies is still emerging, it will continue to grow both in scope and implementation (Kerr & Van Houten, 2020).

Other factors driving adoption were compatibility with the MoH medical response systems, ability to use the applications in remote areas, the need to save lives, the need to control the spread of COVID-19, positive attitude of the surveillance teams toward the applications, and the team work exhibited by the surveillance officers. Von Wyl et al., (2021) concur with these findings in a similar study they conducted in Switzerland in which they noted that eliminating technical hurdles and communicating the benefits of adopting the surveillance applications are crucial in promoting their further uptake and adherence. One of the enthusiastic research participants in Kampala was excited to share a detailed experience of what drove him to easily adopt these COVID-19 surveillance applications:

> *"They are user friendly and capture data in real time. ELIF enters both the patient's details (Name, age, vaccination status, symptoms) and the COVID-19 results. HBC is mainly for those who test positive. Such cases are registered on HBC using a phone or computer. I ask them the convenient time of calling. It captures information of potential contacts of the people the Covid-19 patients stay with in their homes. It helps the medical workers to track the management of Covid-19 of the patients in question. Both of the Applications are linked to the MoH Rapid Diagnostic Surveillance Dashboard. This is the platform that captures all the national results. It is mainly used for the rapid diagnostic tests. The COVID-19 positive reports are referred to the Health Sub Districts."*

The key drivers of adopting these COVID-19 surveillance applications generally relate with socio-demographic segments such as having trust in the government information sources, medical interventions, targeted promotion and marketing strategies for these applications (Gao et al., 2022). A related study was conducted by Priyansyah et al., (2023) in Indonesia to comprehensively understand the public's intention to use PeduliLindung, a contact tracing application for COVID-19. The study revealed that trust in government played a major role in predicting the application's trustworthiness and use.

Barriers of adopting these applications

The major deterrents to the adoption of the COVID-19 surveillance applications were the high costs of data, poor internet connectivity, lack of awareness, limited training, poor facilitation of health workers, heavy workload among health workers, poor ICT skills among surveillance officers, negative attitudes towards the applications, lack of cooperation from the private health facilities, inaccurate information leading to false alerts, delayed responses from the ambulance and lack of cooperation from the members of the community. A number of research participants from Mukono lamented about the inadequate training and negative attitude towards the use of the applications. They commented that "*MoH didn't adequately train rural VHTs on how to use the surveillance applications"* and added that "*The applications are suited for urban dwellers, they are not easily applicable in a rural setting."*

Another challenge was the restriction of the application to only one officer which also zeroes down to inadequate training. This meant that data entry was not possible if the concerned surveillance officer was not available. A nurse based in Kampala had this to say:

"Only one person had the rights to operate the applications in the medical facility. In case that person is not around or on leave, everything comes to a standstill. Only a few people have been trained on how to use them and have accounts.

The use of surveillance applications and e-health in general should not only be enhanced during a crisis like COVID-19 where we see that just a limited number of health professionals are equipped with the necessary skills to operate the surveillance applications. These applications have the capacity to provide rapid medical response to the disadvantaged and marginalized people like the elderly, persons with disabilities and those who stay in remote areas and find difficulties in accessing the physical medical facilities (Fang et al., 2018).

In Wakiso, many respondents raised the issue of poor facilitation which later was reflected in the failure of the health workers to procure data on the gadgets to operate the surveillance applications. A health inspector from Wakiso didn't mince any words when she said that:

"Sometimes they would advise us to use our own phones, download the application and use our own data which was really too much. Sometimes we would load 1000 Uganda Shillings, input the data until the data runs out. Refunding of those monies sometimes takes long. We would just do it to keep the application active but we wouldn't provide complete information."

The COVID-19 surveillance experienced a number of setbacks and barriers. Good enough the MoH and the District COVID-19 focal persons continued to monitor and inspect the situation and took appropriate action were ever they were able to do so. Despite these limitations, such as; inputting incomplete surveillance data, data insecurity, digital health illiteracy, structural inequities and others mentioned above, there is ample evidence that these applications were beneficial for understanding outbreak of the pandemic which tried to create a virtual response to individual screening and contact tracing. The authorities therefore need to constructively evaluate these applications within their digital infrastructure. Addressing these barriers promptly provides important tools for a rigorous improvement of these applications for better management of pandemics in the future (Pandit et al., 2022).

How to improve the effectiveness of the surveillance applications for pandemics

Many suggestions were fronted on how to improve the effectiveness of COVID-19 surveillance applications. These included sensitization of the communities on the use of the ICT applications, continuous training of the surveillance officers, liaising with the application developers to provide on-going technical support, develop more user friendly applications, increase on the number of surveillance officers deployed in the field, lobby for funds from development partners, provide feedback on the alerts from the applications so as to motivate the users of the applications, expand the use of the applications to other non-communicable diseases like malaria. Proper planning for training before rolling out the applications was emphasized by a number of respondents. One from Luzira in Kampala had this to say:

"Continuous training, sensitization of the public about these applications and breaking the stigma. Sometimes on weekends, there were errors in the system and there would be no

> *information technology (IT) staff to attend to the technical glitches until the beginning of the new week."*

It is indeed true that continuous training and sensitization is key in improving the effectiveness of the surveillance applications. Giannini (2013) conducted a study on surveillance applications for hepatocellular carcinoma and noted that continuous education of physicians and patients is of paramount importance when improving the surveillance applications and its benefits . Meanwhile the applications malfunctioning during the weekends without any rapid response until the beginning of the next week is an indicator that many times the authorities dwell so much on the technology and forget the people. There were no technical IT people deployed to monitor the applications on the weekends yet COVID-19 infections could take place any time. As authorities plan for the technology, equal attentions should be placed on the people who use or manage the technology. Everything in ICT is about people and, more specifically, about the emancipatory application of knowledge for and by the people (Saariluoma, 2006). Another clinical officer from Mukono argued that these applications can work better if the required infrastructure is in place. She said that:

> *"There is a need to increase the distribution of electricity because our phone batteries would run out and we didn't have where to charge them until we go back to the town.*

Another participant from Wakiso strongly felt that these applications are used by people. If they were well facilitated, then the rest would just fall in place. He said that "*These field officers need more allowances for this function of surveillance to work harmoniously."* Proper facilitation of the health workers plays a key role in providing incentive for them to operationalize these applications. Another key component is the community appropriateness of data that is provided by the surveillance applications. This may apply either to the application itself or the health professionals receiving the information or using the application. In Kampala Central, one VHT stated that:

> **"***Some of the VHTs are not professional health workers so they sometimes feed information in the application which is not complete, inappropriate and sometimes misleading."*

The Ugandan community is on a learning curve, some health workers were fast learners and easily embraced the technology and used it appropriately while others faced some difficulties and challenges. It was incumbent upon MoH to ensure that the health workers entering the data into the system and those receiving the information from the applications had the required technical training and clinical knowledge for the surveillance system to ably support and guide in diagnostics, therapy and treatment of COVID-19. Indeed, to increase the efficiency and effectiveness of these surveillance applications, Groseclose and Buckeridge (2017) advice paying keen attention on the role played by the system stakeholders, ensuring proper analysis and interpretation of surveillance data, strengthening system monitoring and evaluation and increasing scientific rigor and outcomes-focused research on these surveillance applications and health informatics in general.

Conclusion

The use of ICT-based surveillance applications was largely effective in the management of COVID-19 surveillance applications in Uganda. The findings of the study indicate that the

COVID-19 surveillance applications deployed by the MoH in Uganda included both web-based and non-web-based applications. The ICT surveillance applications provided accurate, authoritative and timely data. However, there were false alerts as result of inaccurate data supplied by the applications. The use of the applications was effective in the reporting and management of COVID-19 from the communities, to the Districts and the MoH. To a greater extent the COVID-19 applications facilitated MoH medical rapid response system. This study also indicted that the ICT surveillance applications were compatible with the manual COVID-19 management systems. The adoption of the COVID-19 surveillance applications was mainly driven by the training of surveillance officers, user friendliness of the applications, and the use of mobile devices. On the other hand, adoption of ICT surveillance applications was deterred by their reliance on internet connectivity, poor facilitation of the surveillance officers, and high costs of data. Furthermore, the study noted that the applications provided reliable data for making rapid diagnostic tests which could also be effective in the management of other non-communicable diseases. There is need for adequate facilitation in terms of increased pay, data, and regular training for surveillance officers for these applications to perform better in case of future pandemics.

Recommendations:

COVID-19 helped in showing the need for health surveillance in the eco system of health care in Uganda. Originally, they were not well paid but now they allocate some funding to help in facilitating the surveillance of COVID-19 and other communicable diseases. This study therefore, recommends the following: -

(i) Conduct massive training and sensitization before rolling out epidemic surveillance applications.

(ii) The MoH should be keen to get feedback on the effectiveness of the surveillance applications from the field.

(iii) Provide proper facilitation of the health workers who operate the applications.

(iv) Deploy professional health workers with required digital skills to operate the applications.

(v) Develop and integrate similar applications to manage the surveillance of other non-communicable but terminal diseases.

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