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Enhancing Tuberculosis Care in Southwestern Uganda: Facilitators and Barriers to Utilizing Mobile Health Technologies

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Abstract
Although mobile health technologies are low-cost approaches that can enhance tuberculosis care, there is a dearth of research about the facilitators and barriers regarding their utilization in enhancing the public–private mix. The aim of this study is to explore the facilitators and barriers to utilizing mobile health technologies in fostering public–private mix for tuberculosis care in Southwestern Uganda, this was a qualitative study that involved in-depth interviews with 13 key informants (private healthcare workers) purposively selected between June and July 2020 due to their active involvement in tuberculosis care from four private hospitals in Mbarara city. An inductive content analysis approach based on the constructs of the consolidated framework for implementation research was used in this study. The main facilitators were related to design quality and packaging, cosmopolitanism, relative advantage, networks and communication, and engaging constructs and these include mapping and linking patients from private hospitals to the referral units; supporting patient care and medication adherence; reducing stigma among patients; enhancing communication between facilities; improving the knowledge and beliefs of healthcare workers and patients; as well as notifying and reporting tuberculosis cases to the Ugandan Ministry of Health. Poor internet connections and lack of knowledge to use mobile health interventions were the barriers that emerged from networks and communications; and knowledge and benefits about the intervention constructs. Mobile health could enhance tuberculosis care by linking the referred patients from private hospitals to public hospitals. Future research should focus on the effectiveness of mobile health technologies in enhancing the public–private mix in tuberculosis care in low-resource settings.

Keywords Mobile health · Tuberculosis · Public–private mix · Facilitators · Barriers · Implementation frameworks

Background

Tuberculosis remains one of the top causes of death globally despite its being curable and preventable (World Health Organization, 2017a, b). Globally, 10 million people developed new tuberculosis infections in 2020 and 1.5 million people died (World Health Organization, 2021). The burden of tuberculosis disease in Uganda remains high with an incidence rate of 196 (117–296) per 100,000 (World Health Organization, 2020a, b). Despite the human immunodeficiency virus-positive tuberculosis incidence rate of 65 per 100,000, Uganda is still ranked among the 30 high tuberculosis burden countries and 30 high tuberculosis/human immunodeficiency virus burden countries in the world (World Health Organization, 2021).

Developing countries continue to struggle to achieve the 2035 global targets of the End-TB strategy. These include achieving a 95% decline in deaths due to tuberculosis, reaching an equivalent 90% reduction in tuberculosis incidence rate from a projected 110 cases/100 000 in 2015 to 10 cases/100 000 or less by 2035, and that by 2020, no tuberculosis-affected person or family should face catastrophic costs due to tuberculosis care (World Health Organization, 2015). Intensified research and innovation is one of the pillars for achieving these targets, under which, research to optimize implementation and impact, and promote innovations is a major action. It has been reported that indeed most innovations cannot be translated into effective local action without careful planning, adaptation, and partnership with

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stakeholders (World Health Organization, 2014) in addition to understanding contextually specific facilitators and barriers to its implementation.

Although previously considered to be better avenues for providing promotive, preventive, and curative components of general healthcare (World Health Organization, 2001), government health facilities are continually becoming more overwhelmed by the increased tuberculosis disease burden, this is in addition to competing priorities that do not permit adequate addressing of the disease burden hence needing supplementation by private health facilities. To address this, the public–private mix was introduced in 2003 by the World Health Organization to involve all the relevant healthcare providers in the provision of tuberculosis care and control (Uplekar, 2003). Public–private mix refers to various strategies and approaches that link all health entities from both private and public sectors to national tuberculosis programs for the expansion of directly observed treatment short course activities (World Health Organization, 2020). There is some evidence that shows that public–private mix is cost-effective for tuberculosis care (Anand et al., 2017), and increases case detection (Asuquo et al., 2015). From 2010 to 2019, there has been a significant contribution of the public–private mix which resulted in an increase in the annual number of case notifications (1.8 million cases in 2019) among the high tuberculosis burden countries (i.e., Bangladesh, India, Indonesia, Myanmar, Nigeria, Pakistan, and the Philippines) (World Health Organization, 2020a).

Despite some global progress in the implementation and expansion of the public–private mix, many private healthcare providers in high-burden countries remain unengaged (Uplekar, 2016). In Uganda, the engagement of private health providers in tuberculosis care and prevention is minimal despite being a significant contributor to health services, with 47% of all hospitals in Uganda being private (Ministry of Health, 2018). Although many patients in Uganda access healthcare through private service providers, most private healthcare providers (such as private clinics and hospitals) remain incapacitated to provide tuberculosis treatment and care (Wynne et al., 2014). They mainly screen patients for symptoms and refer them for better management in government health facilities. This could result in delayed case detection and notification rates.

To address this gap, guidelines for enabling the standardization of the public–private mix for tuberculosis were developed in 2018 by the Uganda Stop TB Partnership and the Ugandan Ministry of Health (Ministry of Health, 2018). According to this report, the implementation of the public–private mix in Uganda is conducted via a phased approach through training and mentorship, to build the capacity of the participating private health facilities to engage in tuberculosis service provision. Progress indicates that a handful of private health practitioners including doctors, nurses, and laboratory personnel from six districts (Mbale, Tororo, Jinja, Iganga, Gulu, and Kitgum) in eastern and Northern Uganda were trained in the implementation of public–private mix activities. In addition to this capacity building, the Ugandan Ministry of Health in partnership with the United States Agency for International Development Defeat tuberculosis project, trained 20 private health practitioners to improve quality tuberculosis care through case notification, detection, and treatment in Kampala, Wakiso, and Mukono Districts in Central region, Uganda. Although this continuous mentorship and coaching resulted in the engagement of over 150 health facilities in the country (Ministry of Health, 2018), facilities and healthcare workers from the southwestern part of the country have not yet had an opportunity to be involved which affects tuberculosis care efforts in the region.

The use of mobile health technologies (e.g., smartphone apps, text messages, wearable devices) in supporting tuberculosis care is highly recommended by the World Health Organization as an emerging opportunity that can close the gaps in tuberculosis care (World Health Organization, 2019). Although their application in tuberculosis care in developing countries is still in its infancy, there is some evidence that they can enhance tuberculosis care through screening and case notification (Tumuhimbise & Musiimenta, 2021a), motivating treatment adherence (Musiimenta et al., 2018, 2019), fostering prenatal service utilization (Musiimenta et al., 2020a, b, 2021; Tumuhimbise et al., 2020), and providing social support to tuberculosis patients (Musiimenta et al., 2020a, b). Mobile health technologies are low-cost applications that can potentially be sensitive to both the private sector ways of working and the expectations of the national tuberculosis programs (Uplekar, 2016), with the ability to produce tremendous results in facilitating the engagement of the private hospitals. However, there is a dearth of research about the facilitators and barriers to their utilization in enhancing the public–private mix. This knowledge could potentially be used to inform the future development of mobile health interventions for engaging private health facilities in tuberculosis care.

The utilization of a theoretical framework like the Consolidated Framework for Implementation Research (CFIR) offers a logical structure for guiding formative evaluations (Damschroder et al., 2009) and understanding the perceptions of stakeholders in evaluating interventions. The CFIR proposed by Damschroder and colleagues is composed of five main domains: (1) intervention characteristics that influence an intervention, which include relative advantage, design quality, and packaging of the mobile health technology being implemented; (2) outer setting which involves the external factors like cosmopolitanism (the degree to which an organization is networked with other external organizations) that could influence the use of mobile health; (3)

inner setting which involves networks and communications, through which the implementation process will proceed or features of mobile health technologies that may foster public–private mix in tuberculosis care; (4) characteristics of individuals involved in utilization of mobile health technologies for public–private mix in tuberculosis care; (5) implementation process that involves active change strategies aimed at individual and organizational level use of mobile health technologies (Damschroder et al., 2009). The framework was established to guide the systematic assessment of multilevel implementation factors that are critical in influencing the implementation of a given intervention, and its effectiveness (Keith et al., 2017). The framework can be applied at any stage of implementation (before, during, and after), which may help in the planning and development of interventions that may be testable based on the specific constructs.

We have previously applied the CFIR in understanding barriers and motivators to private hospitals' engagement in tuberculosis care (Tumuhimbise & Musiimenta, 2021b) and it offers a richer context for discovering facilitators, barriers, and baseline intervention assessment. Therefore, utilizing this framework would lay a foundation for understanding whether or not the intervention will be effective or not if implemented. However, its application in understanding the facilitators and barriers to utilizing mobile health technologies in enhancing the public–private mix for tuberculosis care in Uganda remains unknown. In this paper, guided by the consolidated framework for implementation research, we document an exploratory analysis in which we sought to explore these facilitators and barriers to better inform the design of future interventions aimed at fostering the public–private mix in tuberculosis care.

Methods

Ethical Approval

Official permission was sought and obtained from the participating hospitals where the study was conducted. Ethical approval was obtained from the Mbarara University Research Ethics Committee (Protocol number: 32/03-20) and the Uganda National Council of Science and Technology (Registration number: HS963ES). All participants provided written consent before participating in the study.

Study Design, Setting, and Selection of Participants

We conducted a cross-sectional study with a qualitative research approach that involved in-depth semi-structured interviews with healthcare workers (medical doctors and nurses). The methodology for this study has been described previously (Tumuhimbise & Musiimenta, 2021b). Briefly, the participants were recruited from three private for-profit and one private not-for-profit hospital in Mbarara city, in Southwestern Uganda. These facilities were purposively selected for having relatively large medical establishments, a large number of healthcare workers, being involved in tuberculosis case detection, and being at the center of handling a large number of outpatients in Mbarara city, which increases the likelihood of detection of presumptive tuberculosis cases. After performing symptom-based screening of patients for tuberculosis, all hospitals refer the presumptive tuberculosis patients to Mbarara regional referral hospital which is the only national tuberculosis program facility that manages tuberculosis in Southwestern Uganda.

A total of 13 healthcare workers composed of 11 medical doctors (85%) and two nurses (15%) from four private hospitals in Mbarara city participated in this study. Specifically, participants were included based on the following inclusion criteria: (a) employed medical doctor/nurse in a private hospital setting, (b) have experience in tuberculosis-related activities such as case identification, referral, and treatment, (c) willing and able to give informed consent. The majority of the participants 8 (62%) were male, and were recruited from private for-profit private hospitals (85%) and with at least a few or fewer years of medical practice; details of this study have been described previously (Tumuhimbise & Musiimenta, 2021b).

Data Collection

Between June and July 2020, we purposively recruited 13 key informants based on the inclusion criteria highlighted in the selection of study participants section above. A semi-structured interview guide was developed in the English language, pre-tested to ensure data reliability, validity, and accuracy, and was used to elicit in-depth discussions about the facilitators and barriers to utilizing mobile health technologies. The researcher (WT) who has experience and training in qualitative research and research ethics, conducted semi-structured face-to-face in-depth interviews with the medical doctors and nurses from the identified study sites. Interviews were carried out until thematic saturation was reached at the 13th participant and no new themes were emerging from the data. The interviews involved engaging healthcare workers to tell their stories as prompted by the investigator. Each interview lasted between 30 and 40 min and was carried out in a private convenient place preferred by the respondents. Interviews were recorded digitally with participants' consent and transcribed thereafter. Questions about the perceived facilitators and barriers of mobile health in fostering the public–private mix were elicited. Following each conducted interview, the transcripts were reviewed for quality assurance, clarity, and detail by authors AM, DA,

and FK. A short survey was then administered to the medical doctors and nurses to gather their social demographic details.

Data Analysis

Through the initial review of transcripts, researcher WT developed an initial coding scheme which was reviewed and discussed by authors AM and FK. The inductive content analysis approach (Hseih and Shannon, 2005) was used to generate themes and subthemes from the codebook. Categories about the facilitators and barriers to utilizing mobile health technologies (e.g., referral, supporting medication adherence, and tuberculosis case notification) in fostering the public–private mix in tuberculosis care were extracted from the transcripts. The codebook was reviewed by AM to ensure that the relevant content was extracted. WT assembled the codebook following an iterative approach that was guided by the CFIR. This included category construction of codes related to mapping and linking referred patients to the referral points. It also involved supporting patient care and medication adherence, tuberculosis case notification and reporting themes to represent the content, and writing the operational definitions, elaborations, and illustrative quotes. Intercooled STATA (Statacorp, 2013) was used to describe study participants' characteristics.

Results

This study involved thirteen healthcare workers that included 11 medical doctors and two nurses recruited from four private hospitals due to their active involvement in tuberculosis care like screening and diagnosis. This was aimed at gaining key insights about the facilitators and barriers to utilizing mobile health technologies for enhancing the public–private mix in tuberculosis care among healthcare workers. None of the healthcare workers declined to participate, however, this study only considered healthcare workers who had experience in tuberculosis care (screening, and referring presumptive TB) as described under the inclusion criteria. In addition, private hospitals in southwestern Uganda are relatively small in numbers and underdeveloped to employ a relatively large number of healthcare workers which explains the small number of participants selected for this study. The majority of the participants were from private for-profit private hospitals ($n=11$), and were male ($n=8$), with a median age of 29 years as shown in Table 1.

The following section highlights several facilitators and barriers to utilizing mobile health in fostering the public–private mix in tuberculosis care categorized under the five domains of the consolidated framework for implementation research, namely: the intervention characteristics, outer setting, inner setting, characteristics of the individuals, and the process of implementation. Of the 39 constructs evaluated, only five were assessed based on the relevant themes that emerged from the data concerning the facilitators and barriers to utilizing mobile health in enhancing the public–private mix for tuberculosis care as shown in Table 2. The remaining 34 constructs could have been relevant but were not assessed because they did not yield themes relevant to the study and these include intervention source, evidence strength and quality, relative advantage, adaptability, trialability, complexity, cost under the intervention characteristics domain; patient needs and resources, peer pressure, external policy and incentives under the outer setting domain; structural characteristics, culture, implementation climate, tension for change, compatibility, relative priority, organizational incentives and rewards, goals and feedback, learning climate, readiness for implementation, leadership engagement, available resources, access to knowledge and

Table 1 Participants' demographics

Baseline characteristic	Participants *n*
Median age (IQR)	29 (28–31)
Gender	
Female	5
Male	8
Marital status	
Single	5
Married/partnered	8
Highest educational level	
Certificate	1
Diploma	1
Degree	7
Masters	3
PhD	1
Designation	
Nurse	2
Doctor	11
Number of years in general medical practice	
1–3	7
4–5	2
> 5	4
TB services provided by healthcare workers	
Screen for TB[a]	13
Screen and manage[b]	5
Screen and refer[c]	8

IQR interquartile range

[a]All participants were able to screen for TB

[b]Five participants were able to screen and manage TB cases at the, while

[c]Eight participants were able to screen and refer patients

Table 2 CFIR constructs and their related facilitators or barriers to utilizing mHealth technologies in enhancing the public–private mix for TB care

CFIR domain	CFIR construct	Facilitator or Barrier	Explanation for facilitators and barriers
Intervention Characteristics	Design quality and packaging	Facilitator	mHealth was perceived to be excellent in ensuring TB case notification and reporting
	Relative advantage	Facilitator	Perceived relative advantage of reducing stigma among patients
Outer setting	Cosmopolitanism	Facilitator	mHealth was perceived to map and link the referred patients from private to public hospitals
Inner setting	Networks and communications	Barrier	Poor internet connection would limit the usability of internet-based interventions
		Facilitator	Mobile health was perceived to enhance communication between facilities
Characteristics of individuals	Knowledge and beliefs about the intervention	Barrier	Lack of knowledge to use the mHealth technology among healthcare workers
		Facilitator	Mobile health technology was perceived to improve the knowledge and beliefs of healthcare workers and patients
The process of implementation	Engaging	Facilitator	Supporting patient care and medication adherence

information under the inner setting domain; self-efficacy, individual stage of change, individual identification with organization, other personal attributes under the characteristics of individuals domain, and planning, opinion leaders, formally appointed internal implementation leaders, champions, external change agents, executing, reflecting, and evaluating under the process domain.

Facilitators of utilizing mobile health arose from design and quality packaging, relative advantage, cosmopolitanism, networks and communications, knowledge, and beliefs about the intervention and engaging constructs. These include the potential of mobile health to map and link the referred patients to the referral units; support patient care and medication adherence; reduce stigma; improve knowledge and beliefs of healthcare workers and patients; and notify and report tuberculosis cases, respectively. Barriers to utilizing mobile health technologies arose from networks and communications, and knowledge and beliefs about the intervention construct include poor internet connection would limit the usability of internet-based interventions; and lack of knowledge to use several mobile health technologies among healthcare workers.

Intervention Characteristics

Mobile health was perceived to be an excellent mechanism for tuberculosis case notification and reporting. Participants highlighted that mobile health can enable timely reporting and notifying of tuberculosis cases to the Ugandan Ministry of Health on what is happening in the private hospitals. The technological enhancement of various mobile health technologies that include modern report generation tools enhances remote uploading of daily, weekly reports about activities to the government. This would help in reducing the time to notify tuberculosis cases between different health centers and updating the national database about the number of cases. One participant from Hospital 3 reported that

> Mobile health can help in reporting and giving timely reports. You can design an app where we can upload the work we are doing weekly so that we constantly update the government on the work that is going on. If there is a case that I have diagnosed, I can easily upload patients' details in the mobile application, which can quickly update the number of cases at the national level from both the public and private hospitals. (Medical Doctor, Hospital 3).

Mobile health technologies were perceived to have a relative advantage of reducing stigma among patients referred from private to public hospitals. Participants noted that patients fear going to the places of referral due to fear of being seen in tuberculosis clinics in public hospitals but with mobile health technologies since the healthcare workers at the public facilities will have already been notified about the incoming patient, it gives the patients confidence to go and receive faster care.

> Mobile health can help in reducing stigma. One of the stumbling blocks in tuberculosis care is the challenges the patients are likely to find on the other side, first of all, some have this notion that tuberculosis is not curable and some are worried that when they reach there they will be tossed up but with mobile health technologies like apps, the patient will reach the facility when he or she is already known by the healthcare worker through notifications. (Medical Doctor, Hospital 3).

Outer Setting

Mobile health was reported to have the potential to map and link presumptive tuberculosis patients that have been referred from private hospitals to the hospital facilities where they have been referred for tuberculosis services. The ability of mobile health to ensure interconnectedness across different settings, and transcending geographical boundaries puts it at an advantage in establishing linkages between public and private hospital facilities. This involves aiding in the identification of presumptive tuberculosis patients and ensuring that they have been linked or connected to the nearest clinics that provide the required tuberculosis services. One medical doctor from Hospital 1 reported that

> Mobile health can help in mapping and linking the patients to the nearest health facility that offers tuberculosis services. (Medical Doctor, Hospital 1).

In addition, mobile health technologies were perceived to be useful in informing the referral centers about the details of an individual patient that needs to be attended to, which could potentially result in faster services. One participant from Hospital 4 described that

> If I get a presumptive tuberculosis patient at a private facility, through the mobile app, I can inform the tuberculosis clinic at the public hospital which is licensed to provide tuberculosis services that on a certain day, a patient from a certain hospital is coming, it will result in faster care on the presumptive tuberculosis case. (Medical Doctor, Hospital 4).

Inner Setting

Mobile health was perceived to enhance communication between facilities by allowing healthcare workers from both the private and public health facilities to communicate with each other about presumptive patients that were referred from private to public hospitals. One participant from Hospital 2 noted that

> Mobile health provides the easiest way for healthcare workers to communicate with each other about the referred patient. An application that can be used by healthcare workers at private hospitals to notify the healthcare workers at public hospitals about the patient that has been referred through SMS reminders might be helpful. When a patient is received at the facility, healthcare workers can also immediately reply via the application which brings easy communication across facilities. Using mobile health can provide an interface for two-way chatting via SMS or Video between healthcare workers about the progress of the patient. (Medical Doctor, Hospital 2).

On the other hand, participants raised the concern of poor internet connection (e.g., slow connections or lack of internet) which might affect the usability of mobile health interventions that rely entirely on the internet. If a hospital facility does not have a well-set up internet infrastructure for ensuring the running of mobile health interventions that are internet-based, it might hinder the adoption and use of the intervention.

> If the app uses the internet, in some places, there are poor network connections, which might affect the operation of the intervention. (Medical Doctor, Hospital 3).

Characteristics of Individuals

Mobile health technology was perceived to improve the knowledge and beliefs of healthcare workers and patients by enhancing learning about how to care for tuberculosis among healthcare workers and providing information to patients about the benefits of medication adherence which in long run enhance better health outcome. One participant from Hospital 4 noted that

> I think mobile health technology can be used as a tool for enhancing learning for healthcare workers, especially about best practices for tuberculosis care like screening, and remotely relay information to patients wherever they are about the side effects of the drugs they are taking and information on benefits of medication adherence. (Medical Doctor, Hospital 4)

However, on the other hand, some participants expressed concerns about the lack of knowledge among health workers to use the developed mobile applications, which might hinder the operation and implementation of the technology due to abandonment by the intended user. One medical doctor from Hospital 2 reported that

> Some health workers may not know how to use the app and in the long run, may abandon it. (Medical Doctor, Hospital 2).

The Process of Implementation

Healthcare workers perceived mobile health as a tool for enhancing coordinated patient care and monitoring by facilitating communication between patients and healthcare workers across health facilities. One medical doctor from Hospital 1 reported that

> I think mobile health would help if someone had an app on their phone installed that would keep the patient and the health care providers in touch, which would

> ensure better adherence to the drugs among patients, and better follow-up. (Medical Doctor, Hospital 1).

The communication between healthcare workers and patients via short messaging service reminders may enhance medication adherence, and encourage patients to attend their clinical appointments as scheduled. A medical doctor from Hospital 4 reported that

> Mobile health can help in monitoring patients to take their medication on time, and also help them know when to refill their drugs and also reminders of when to come back to the clinic. (Medical Doctor, Hospital 4).

Discussion

Guided by the CFIR, several themes emerged from the data and were categorized per the relevant constructs of the six domains of the framework. These constructs include design quality and packaging; cosmopolitanism; and engaging where facilitators for mobile health technologies emerged from while networks and communications; knowledge and benefits about the intervention constructs yielded barriers to mobile health. The facilitators included mapping and linking patients from private hospitals to the referral units; supporting patient care and medication adherence; reducing stigma; enhancing communication between facilities; improving the knowledge and beliefs of healthcare workers and patients as well as notifying and reporting tuberculosis cases to the Ugandan Ministry of Health. The identified barriers were poor internet connections and lack of knowledge to use mobile health interventions.

The potential of mobile health technologies to map and link referred patients to the referral points could eliminate the risk of loss of patients along the pathway of care but could also result in enhanced patient care and monitoring. Through such mobile health interventions, the proportion of patients that reach their expected referral points and who get started on medication on time could increase, with subsequent reductions in diagnostic and drug initiation delays as evidenced in India (Chadha et al., 2017). Most of the private hospitals in Uganda are not accredited to provide tuberculosis services, this limits their efforts and engagement in tuberculosis care despite being at the center of receiving a majority (48%) of the population who seek healthcare compared to the government (public) health facilities (34%), 14% who preferred to go to privately owned pharmacies, 1% who preferred field workers/ Village health teams, and 3% to shops, outreach services, traditional practitioners, markets, and private doctors (Uganda Bureau of Statistics, 2017). Therefore, as a common practice, most of these private hospitals refer presumptive tuberculosis patients to public hospitals (O'hanlon et al., 2017). However, the lack of mechanisms for following up on these patients in private hospitals (Tumuhimbise & Musiimenta, 2021b) still stifles tuberculosis control efforts. In this regard, the adoption of the current information communication technologies like smartphones and mobile apps (Mobile health) as a mechanism for following up on these patients after referral could ensure easier patient tracking and successful referral processes from private to public health facilities. The implementation and utilization of mobile health in fostering the public–private mix in Africa remain unknown, yet most countries in Africa still grapple with a high number of tuberculosis cases (25% of the global tuberculosis cases come from Africa) (World Health Organization, 2020a). Understanding how mobile health is utilized to engage the private sector in tuberculosis care, especially in African settings, has the potential to ensure better tuberculosis disease outcomes in Africa (Tumuhimbise & Musiimenta, 2021a).

The potential of mobile health technologies to support patient care and medication adherence among tuberculosis patients could enhance the timely intake of medication and the attendance of hospital appointments for pill refills (Gashu et al., 2019). Particularly in our study, participants reported that mobile health technology would enable healthcare workers to monitor patients thus enabling adherence to medication and attendance of hospital appointments. Mobile health provides quick access to information for both patients and healthcare workers and offers a qualitative and quantitative interaction between the healthcare providers and the patients (Tumuhimbise et al., 2020). Several studies utilizing mobile health technologies for supporting medication adherence among both tuberculosis and human immunodeficiency virus patients have been conducted in Uganda (Musiimenta et al., 2018, 2019) and were found to be acceptable and feasible. A randomized control trial (Mohammed et al., 2016) that was conducted in Karachi Pakistan utilized two-way short message service reminders to encourage newly diagnosed patients from public and private health facilities to take their medication. However, the utilization of mobile health technologies between the public and private health facilities in Uganda for tuberculosis care is unknown. This leaves a research gap and calls for a special investigation on how mobile health technologies can be utilized for enhancing the public–private mix in tuberculosis care.

Our study findings report that mobile health interventions could also enhance quick and timely notification of tuberculosis cases from private health facilities to national tuberculosis programs to ensure better planning of tuberculosis management services. Notifying cases is key in enhancing the tracking and management of tuberculosis patients. The tuberculosis case notification rate in Uganda is mostly done by public hospitals (86%), while private for-profit facilities notify only 1% (Ministry of Health, 2020). The report shows

that most of the cases are still missed where about 30,000 people with tuberculosis symptoms were neither notified nor diagnosed in 2018/2019. This implies a need for establishing mechanisms for ensuring that all cases are notified. Mobile health could play a role in improving notification of every diagnosed case as shown in the literature. According to a scoping review by Tumuhimbise and Musiimenta, mobile health interventions like mobile applications have been utilized in the notification of tuberculosis cases in Vietnam India, Indonesia, Pakistan, and Vietnam (Tumuhimbise & Musiimenta, 2021a). A referral and reporting back mobile phone application was found to be acceptable and feasible for notifying tuberculosis cases among private practitioners in Indonesia (Lestari et al., 2017). Although mobile health has been utilized in the notification of tuberculosis cases elsewhere, its experience among healthcare workers in settings like Uganda where healthcare workers might be overwhelmed with a large number of clients (high patient–doctor ratio) and fail to find time for real-time use of the application to notify cases; this is being explored in our ongoing research investigation.

Our findings show that mobile health technologies have the potential to reduce stigma among patients referred from private to public hospitals. Literature has shown the potential of mobile health to reduce human immunodeficiency virus-related stigma among youths in the United States (Mulawa et al., 2021), however, very few interventions aimed at reducing tuberculosis stigma have been utilized (Courtwright & Turner, 2010), thus a need for exploring the potential of mobile health in stigma reduction in tuberculosis care.

In this study, participants raised concerns about the lack of knowledge to use the developed mobile applications. User involvement during intervention development may play a role in acquainting system end-users with the intervention which in the long run could facilitate the acceptability of the developed application among users (Goold et al., 2006). This approach helps the developers to understand user behaviors, requirements, and skills at each phase of the design (Wever et al., 2008). Training users on how to use the application before implementation may improve usability and address this concern. Users who are not well trained to use find it hard to use the technology (Gurupur & Wan, 2017). Therefore, system implementers should ensure conducting initial training sessions before rolling out the interventions. In addition, developers should develop interventions that are easy to use (Tumuhimbise & Musiimenta, 2021a), which are intended to ease the work of healthcare workers.

The reported poor internet connectivity or lack of internet access especially for interventions that entirely run on the internet or require the internet to function can hinder the usability of the application and result in the abandonment of the interventions (Katusiime & Pinkwart, 2019). Mobile health interventions that entirely rely on the internet to operate, require stable internet connections to ensure thorough operability (Chen et al., 2016). The jurisdiction of the cost burden of internet packages for running these internet-based interventions must be clearly defined lest the cost burden on the users cannot be sustained in the long run. Mobile health interventions should strive to remove the cost burden from the users if successful implementation is to be ensured (Zhou et al., 2019). Considering the development of standalone interventions or applications that do not require the internet to operate can address this concern.

The general implementation and coverage of the public–private mix for tuberculosis in Uganda require deliberate efforts to ensure that all private health facilities are involved in tuberculosis care if success and better health outcomes are to be realized. Engaging and empowering the private sector in tuberculosis disease management is crucial in enhancing the reduction of unnecessary deaths and sufferings due to substandard diagnosis, inappropriate treatment, and care that occur in the private sector, thus reduction in catastrophic costs (World Health Organization, 2018a, 2018b). Successful tuberculosis control efforts cannot be achieved globally if private providers are not brought on board to tackle tuberculosis disease.

Unanswered Questions and Future Research

Our findings recognize that there is a need for future researchers to assess the utilization of mobile health technologies for following up patients referred from private to public hospitals in African settings to ascertain its effectiveness on tuberculosis care outcomes and its contribution to the public–private mix efforts for tuberculosis care. Exploring the real-life experiences of how mobile health can be used to foster the establishment of the public–private mix is key in informing policy formulation to address tuberculosis care outcomes. There is also a need to carry out a systematic assessment of how several constructs of the consolidated framework for implementation research (which did not yield themes in this study) influence the utilization of mobile health for enhancing the public–private mix in tuberculosis care.

Implications for Policy and Practice Makers

The utilization of mobile health in tuberculosis care among private hospitals in Uganda is lacking. This leaves its benefits in the achievement of better health outcomes and public–private mix unknown. Our findings imply that mobile health could enhance tuberculosis care through linking and following up the referred patients from private to public hospitals. Our study implies that mobile health can be a cost-effective solution for enhancing the full integration and engagement of

the private healthcare facilities in tuberculosis care thus the achievement of the public–private mix.

The implementation of mobile health interventions requires the training of users to equip them with skills to enable intervention acceptability and usability. Mobile health interventions that entirely rely on the internet to operate, require stable internet connections to ensure thorough operability. Standalone applications that do not require the internet to operate can offer better alternatives. Mobile health interventions should remove the cost burden from the users if successful implementation is to be ensured.

Strengths and Limitations of the Study

This study has several strengths; first, it identifies key insights about the facilitators to utilizing mobile health technologies from the front line private medical healthcare workers in a low-resource setting which provides an evidence base for the development of future interventions in similar settings. Secondly, to the best of our knowledge, this study is the first to report pre-intervention perceptions of healthcare workers from private hospitals about the facilitators of utilizing mobile health technologies for fostering the public–private mix in tuberculosis care. Lastly, this study is based on the key implementation research principle of formative research and analysis of data based on a theoretical implementation framework—the CFIR.

Our study is not without limitations that should be considered during the interpretation of the research findings. First, being a formative study, the investigator solicited the perceptions of private healthcare workers about the facilitators and barriers of using mobile health in enhancing the public–private mix for tuberculosis care before they could use the intervention in real life. The results, therefore, do not document the practical real-life experiences of utilizing the mobile health intervention in tuberculosis care. Second, our study employed a purposive sampling approach for recruiting key informants—11 medical doctors compared to two nurses. Although these were the only healthcare workers with experience in TB-related case identification, referral, and treatment, the selection reflects a highly skewed representation of participants and should be interpreted with care. Third, the inclusion of a very low number of nurses whose perspectives may differ from those of medical doctors could have been missed. Lastly, this study was conducted in private hospitals in an urban setting; this could limit the generalizability of our findings in rural settings, where private hospital operations and practices might be different.

Conclusion

The utilization of mobile health could enhance the implementation of the public–private mix by improving care among patients and enhancing better treatment outcomes like early diagnosis and drug initiation thus limiting the risk of infection at both the community and household level. Understanding the facilitators and barriers to utilizing mobile health technologies in enhancing the public–private mix for tuberculosis care is essential to understanding how they can be effectively used in tuberculosis treatment and care. Findings from this formative study are informing the development of an mHealth intervention to enhance the engagement of private hospitals in tuberculosis care, which the authors are currently working on.

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Declarations

Conflict of interest None declared.

References

Anand, T., Babu, R., Jacob, A. G., Sagili, K., & Chadha, S. S. (2017). Enhancing the role of private practitioners in tuberculosis prevention and care activities in India. *Lung India, 34*(6), 538. https://doi.org/10.4103/0970-2113.217577

Asuquo, A. E., Pokam, B. D. T., Ibeneme, E., & EkpereonneObot-Asuquo, E. V. P. (2015). A public–private partnership to reduce tuberculosis burden in Akwa Ibom State Nigeria. *International Journal of Mycobacteriology, 4*(2), 143–150. https://doi.org/10.1016/j.ijmyco.2015.04.002

Chadha, S., Trivedi, A., Nagaraja, S., & Sagili, K. (2017). Using mHealth to enhance TB referrals in a tribal district of India. *Public Health Action, 7*(2), 123–126. https://doi.org/10.5588/pha.16.0080

Chen, M., Qian, Y., Mao, S., Tang, W., & Yang, X. (2016). Software-defined mobile networks security. *Mobile Networks and Applications, 21*(5), 729–743.

Courtwright, A., & Turner, A. N. (2010). Tuberculosis and stigmatization: Pathways and interventions. *Public Health Reports, 125*(4), 34–42.

Damschroder, L. J., Aron, D. C., Keith, R. E., Kirsh, S. R., Alexander, J. A., & Lowery, J. C. (2009). Fostering implementation of health services research findings into practice: A consolidated framework for advancing implementation science. *Implementation Science, 4*(1), 1–15. https://doi.org/10.1186/1748-5908-4-50

Gashu, K. D., Gelaye, K. A., Lester, R., & Tilahun, B. (2019). Combined effect of pill refilling and self-medication reminder system on patients' adherence to tuberculosis treatment during continuation phase in Northwest Ethiopia: A study protocol for randomised controlled trial. *BMJ Health & Care Informatics, 26*(1), 5.

Goold, P., Bustard, S., Ferguson, E., Carlin, E., Neal, K., & Bowman, C. (2006). Pilot study in the development of an interactive multimedia learning environment for sexual health interventions: A focus group approach. *Health Education Research, 21*(1), 15–25. https://doi.org/10.1093/her/cyh040

Gurupur, V. P., & Wan, T. T. (2017). Challenges in implementing mHealth interventions: a technical perspective. *Mhealth*. https://doi.org/10.21037/mhealth.2017.07.05

Katusiime, J., & Pinkwart, N. (2019). A review of privacy and usability issues in mobile health systems: Role of external factors. *Health Informatics Journal, 25*(3), 935–950.

Keith, R. E., Crosson, J. C., O'Malley, A. S., Cromp, D., & Taylor, E. F. (2017). Using the consolidated framework for implementation research (CFIR) to produce actionable findings: A rapid-cycle evaluation approach to improving implementation. *Implementation Science, 12*(1), 1–12.

Lestari, B. W., Arisanti, N., Siregar, A. Y., Sihaloho, E. D., Budiman, G., Hill, P. C., et al. (2017). Feasibility study of strengthening the public–private partnership for tuberculosis case detection in Bandung City Indonesia. *BMC Research Notes, 10*(1), 1–6. https://doi.org/10.1186/s13104-017-2701-y

Ministry of Health. (2020). National strategic plan for tuberculosis and leprosy control 2020/2021–2024/2025.

Ministry of Health. (2018). A bulletin of the national tuberculosis and leprosy program. Quarterly Bulletin.

Mohammed, S., Glennerster, R., & Khan, A. J. (2016). Impact of a daily SMS medication reminder system on tuberculosis treatment outcomes: A randomized controlled trial. *PLoS ONE, 11*(11), e0162944. https://doi.org/10.1371/journal.pone.0162944

Mulawa, M. I., Rosengren, A. L., Amico, K. R., Hightow-Weidman, L. B., & Muessig, K. E. (2021). mHealth to reduce HIV-related stigma among youth in the United States: A scoping review. *Mhealth*. https://doi.org/10.21037/mhealth-20-68

Musiimenta, A., Atukunda, E. C., Tumuhimbise, W., Pisarski, E. E., Tam, M., Wyatt, M. A., et al. (2018). Acceptability and feasibility of real-time antiretroviral therapy adherence interventions in rural Uganda: Mixed-method pilot randomized controlled trial. *JMIR mHealth and uHealth, 6*(5), e9031.

Musiimenta, A., Tumuhimbise, W., Atukunda, E. C., Mugaba, A. T., Muzoora, C., Armstrong-Hough, M., et al. (2020a). Mobile health technologies may be acceptable tools for providing social support to tuberculosis patients in rural Uganda: A parallel mixed-method study. *Tuberculosis Research and Treatment*. https://doi.org/10.1155/2020/7401045

Musiimenta, A., Tumuhimbise, W., Mugaba, A. T., Muzoora, C., Armstrong-Hough, M., Bangsberg, D., & Haberer, J. E. (2019). Digital monitoring technologies could enhance tuberculosis medication adherence in Uganda: Mixed methods study. *JCTUBE, 17*, 100119. https://doi.org/10.1016/j.jctube.2019.100119

Musiimenta, A., Tumuhimbise, W., Mugyenyi, G., Katusiime, J., Atukunda, E. C., & Pinkwart, N. (2020b). Mobile phone-based multimedia application could improve maternal health in rural southwestern Uganda: mixed methods study. *Online Journal of Public Health Informatics, 12*(1), 15.

Musiimenta, A., Tumuhimbise, W., Pinkwart, N., Katusiime, J., Mugyenyi, G., & Atukunda, E. C. (2021). A mobile phone-based multimedia intervention to support maternal health is acceptable and feasible among illiterate pregnant women in Uganda: Qualitative findings from a pilot randomized controlled trial. *Digital Health, 7*, 2055207620986296. https://doi.org/10.1177/2055207620986296

O'hanlon, B., Nakyanzi, A., Musembi, V., Busulwa, I., Husband, R., Okumu R, & Kanneganti, S. (2017). Exploring partnership opportunities to achieve universal health access: 2016 Uganda Private Sector Assessment in Health. 2017.

Statacorp. (2013). Stata Statistical Software Release 13; StataCorp, College Station

Tumuhimbise, W., Atukunda, E. C., Ayebaza, S., Katusiime, J., Mugyenyi, G., Pinkwart, N., & Musiimenta, A. (2020). Maternal health-related barriers and the potentials of mobile health technologies: Qualitative findings from a pilot randomized controlled trial in rural southwestern Uganda. *Journal of Family Medicine and Primary Care, 9*(7), 3657. https://doi.org/10.4103/jfmpc.jfmpc_281_20

Tumuhimbise, W., & Musiimenta, A. (2021a). A review of mobile health interventions for public private mix in tuberculosis care. *Internet Interventions,*. https://doi.org/10.1016/j.invent.2021.100417

Tumuhimbise, W., & Musiimenta, A. (2021b). Barriers and motivators of private hospitals' engagement in tuberculosis care in Uganda. *GIRA,*. https://doi.org/10.1007/s43477-021-00030-3

Uganda Bureau of Statistics. (2017). Uganda National Household Survey 2016/2017 Report. UBOS.

Uplekar, M. (2003). Involving private health care providers in delivery of TB care: Global strategy. *Tuberculosis, 83*(1–3), 156–164. https://doi.org/10.1016/s1472-9792(02)00073-2

Uplekar, M. (2016). Public-private mix for tuberculosis care and prevention: What progress? What prospects? *IJTLD, 20*(11), 1424–1429. https://doi.org/10.5588/ijtld.15.0536

Wever, R., Van Kuijk, J., & Boks, C. (2008). User-centred design for sustainable behaviour. *International Journal of Sustainable Engineering, 1*(1), 9–20. https://doi.org/10.1080/19397030802166205

World Health Oganization. (2021). Global Tuberculosis Report 2021.

World Health Oganization. (2015). Implementación de la estrategia Fin de la TB. Available from: http://www.who.int/tb/publications/2015/end_tb_essential_spanish_web.pdf.

World Health Oganization. (2020). *Tuberculosis profile: Uganda. World Health Organization* [Online]. Available: https://worldhealthorg.shinyapps.io/tb_profiles/?_inputs_&entity_type=%22country%22&lan=%22EN%22&iso2=%22UG%22 [Accessed 19th April 2022].

World Health Organization. (2001). Involving private practitioners in tuberculosis control: issues, interventions, and emerging policy framework. In Involving private practitioners in tuberculosis control: issues, interventions, and emerging policy framework.

World Health Organization. (2014). The end TB strategy. Global strategy and targets for tuberculosis prevention, care and control after 2015.

World Health Organization. (2017a). Handbook for the use of digital technologies to support tuberculosis medication adherence.
World Health Organization. (2017b). Public-Private Mix for TB Care and Prevention.
World Health Organization. (2018a). Engaging private health care providers in TB care and prevention: A landscape analysis.
World Health Organization. (2018b). Public–private mix for TB prevention and care: a roadmap. World Health Organization.
World Health Organization. (2019). Global tuberculosis report 2019.
World Health Organization. (2020a). Global tuberculosis report 2020a.
World Health Organization. (2020b) Tuberculosis profile: Uganda 2020b [cited 2021 21st July]. Available from: https://worldhealthorg.shinyapps.io/tb_profiles/?_inputs_&entity_type=%22country%22&lan=%22EN%22&iso2=%22UG%22.
Wynne, A., Richter, S., Banura, L., & Kipp, W. (2014). Challenges in tuberculosis care in Western Uganda: Health care worker and patient perspectives. *International Journal of Africa Nursing Sciences, 1*, 6–10. https://doi.org/10.1016/j.ijans.2014.05.001
Zhou, L., Bao, J., Watzlaf, V., & Parmanto, B. (2019). Barriers to and facilitators of the use of mobile health apps from a security perspective: Mixed-methods study. *JMIR mHealth and uHealth, 7*(4), e11223. https://doi.org/10.2196/11223