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A review of mobile health interventions for public private mix in tuberculosis care

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ABSTRACT

Background: The World Health Organization (WHO) recommends the use of mobile health (mHealth) technologies as emerging opportunities to closing the gaps in Tuberculosis (TB) care through enhancing Public Private Mix (PPM). However, little is known about mHealth interventions that have been used for enhancing PPM in TB care, those that worked and those that did not.

Objective: This review summarizes the published evidence on the utilization and effectiveness of mHealth interventions for public private mix in TB care from literature.

Methods: Google scholar, PUBMED, IEEE Xplore and ScienceDirect databases were searched for peer reviewed literature from 1st January 2003 to 31st December 2020 for studies about the mHealth interventions for public private mix in TB care. This was guided by the scoping review methodology proposed by Arksey and O′ Malley. In order to assess the quality of the selected studies, mHealth evidence reporting and assessment (mERA) checklist was utilized. Studies that discussed the utilization of mHealth interventions for implementing PPM in TB care were included. Nine studies met the inclusion criteria and were analyzed for review.

Results: The review found out the application of mHealth in Public Private Mix in TB care through the following ways; 1) TB screening, 2) TB case notification 3) TB treatment adherence 4) data collection and management 5) patient referral and follow up, and 6) education. This resulted into high user experience, significant time reduction in data aggregation, increased case notification and referrals and proactive tracking and provision of follow up care hence reduced treatment and completion gaps. One study yielded suboptimal utilization due to the technical and operational challenges encountered by the healthcare workers.

Conclusion: Although this scoping review highlights the role of mHealth technologies in enhancing PPM in TB care, its utilization is still limited in African settings. No Africa-based study was identified by this review. Future studies should focus on assessing the utilization of mHealth for PPM in Africa.

1. Introduction

An estimate of 1.4 million people died due to Tuberculosis (TB) disease in 2019 (WHO, 2020) despite its being curable. TB is ranked among the top 10 causes of death worldwide (WHO TB fact sheet, 2017b). World Health Organization (WHO) recommends the engagement of the private healthcare providers in provision of TB services as a strategic action in response to high estimate of TB prevalence globally (WHO, 2001) because many private healthcare providers "treat a large portion of TB patients which may be distant from the national TB Programme" (WHO Digital Handbook, 2017a).

The private health sector initially was excluded from providing public health initiatives like Tuberculosis programmes because the government health facilities were thought to be better avenues for offering promotive, preventive, curative components of healthcare (WHO, 2001). However, with increase in the global TB burden, the government facilities managing TB disease were overwhelmed— the need to engage private healthcare workers in TB care became necessary. In an effort to supplement and expand the DOTS (Directly Observed Treatment short course) and supplement the TB disease management efforts globally, the WHO recommended the Public Private Mix model (PPM) in 2003 (Uplekar, 2003).

PPM refers to various strategies and approaches that link all healthcare entities from both private and public sectors to national

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tuberculosis programmes for expansion of DOTS activities (WHO, 2004). PPM includes collaborating with all relevant healthcare providers from both public and private sectors to undertake one or more tasks related to delivering high quality TB care (Uplekar, 2016). The government offers policy and guidelines whereas private facilities detect TB cases, and at times refer them to NTPs. When the NTP receive these cases, they confirm the diagnosis, provide further management and may send the patients to local private providers for treatment and management (Lei et al., 2015). The implementation of PPM has proved to improve case detection and holding in several countries like Nigeria (Asuquo et al., 2015), Myanmar (Nwe et al., 2017) and India (Dewan et al., 2006). The PPM approach can reduce the financial burden from patients receiving TB care by providing free drugs that patients can access from private health facilities (Anand et al., 2017). From 2010 to 2019, a significant contribution of PPM towards TB case notification (1.8 million cases in 2019) has been registered among the high TB burden countries (Bangladesh, India, Indonesia, Myanmar, Nigeria, Pakistan, and the Philippines), according to the WHO's 2020 Global TB Report (WHO, 2020). This report also indicates increase in TB case notification from 2010 to 2019 (33% of cases in Eswatini, 15% in Ethiopia, 20% in Ghana, 17% in Kenya and 21% in Malawi) as a result of public private mix.

Despite the progress registered in the involvement of private providers and the implementation of PPM, many healthcare providers remain unengaged especially in high TB incident countries (Uplekar, 2016). This limited involvement is attributed to the lack of commitment between the public and private sectors to work together, high economic costs involved, time and effort needed to establish the Public Private Mix programmes (e.g. collaboration, regulation, and stewardship). This is common in developing countries (Naqvi et al., 2012) where most of the private sector doesn't provide high quality TB care (Lei et al., 2015), lack adequate training in TB management (screening, diagnosis and care) thus fragmented, incomplete and inappropriate treatment (Slevin et al., 2014) and lack funding for engaging in TB care (WHO, 2018b) resulting into failure to successfully implement the PPM in TB care.

The use of digital technologies (e.g. text messages, wearable devices, mobile phones applications) is highly recommended as emerging opportunities to closing the gaps in TB treatment and care (WHO Global TB report, 2017b). Such technologies have the potential to identify missing people with TB (WHO, 2018a), and foster TB care through case identification, diagnosis, notification, reporting, monitoring drug adherence among different sectors (WHO Digital Health Handbook, 2017a). The widespread ownership of cell phones and mobile cellular network coverage in Africa offers a cost effective scientific promise for the implementation of mobile-based interventions (Pew Research Centre, 2015; Musiimenta et al., 2018). Compared to other categories of digital technologies, mHealth offers a cost effective alternative for improving health in limited resource settings. It is projected that 84% of the total African population will have access to SIM connection by 2025 (GSMA, 2020) which implies the availability of mobile phone market. mHealth technologies are less expensive, with the potential to reach a wide client base and the hard to reach groups (Evans et al., 2016; Deglise et al., 2012). Capitalizing on such technologies has potential to bring more mobile subscribers on board as far as health is concerned. mHealth technologies can potentially advance the quality and coverage of healthcare and increase health information access (WHO, 2018a). Despite the widespread adoption of mobile phones, literature about the use of mHealth in supporting PPM for TB care remains limited.

Several literature reviews (Lee et al., 2020; Ngwatu et al., 2018; Subbaraman et al., 2018; Alipanah et al., 2018) have documented a number of digital health technologies used in TB control. However, those documenting the utilization and effectiveness of these mHealth technologies for enhancing public private mix are lacking. Although there are some mHealth interventions that are gradually being integrated in TB care to enhance the public private mix, to the best of our knowledge, there has not been a scoping review of mHealth interventions for PPM in TB care. Thus, it remains unclear which interventions have been utilized for PPM in TB care. This review was conducted to synthesize the evidence of the existing mHealth interventions for PPM in TB care and their effectiveness from the existing literature, which can inform the replication of successful interventions and identify areas of improvement like feasibility, acceptability, and efficacy of the implemented interventions in TB care.

2. Methods

2.1. Scoping review methodology

The scoping review methodology approach by Arksey and O'Malley comprised of six key steps i) identifying the research question, ii) identifying relevant studies; iii) study selection iv) charting data v) collating, summarizing and reporting results and vi) consultation guided this review (Arksey and O'Malley, 2005). The methodology was adopted for this review because it enables researchers to obtain a quick overview of the existing literature on the research topic (Lentferink et al., 2017) and allows the inclusion of various types of studies other than randomized trials (Arksey and O'Malley, 2005).

2.2. Identification of studies

This review was conducted using a highly sensitive search strategy in order to identify, screen and analyze all studies that discussed mHealth interventions for Public Private Mix in TB care. Articles published between 2003 and 2020 were reviewed. This was because the PPM was officially recommended by WHO in 2003 to involve all relevant health care workers in TB control (Uplekar, 2003). An initial database search yielded 347 hits (without duplicates), of which nine articles met the inclusion criteria. Details of these nine studies, including details of the interventions evaluated, are listed in Table 1.

The search for the review aimed at addressing the following research questions 1) What are the mHealth interventions for public private mix in TB care?" 2) Which mHealth interventions worked in the implementation of public private mix for TB care? and why did they work as well as which interventions didn't work and why didn't they work?

2.3. Search strategy

Google Scholar, PUBMED, IEEE Xplore and ScienceDirect databases were searched in June 2020 and May 2021 because of their highly indexing and integration capacity. The search aimed at identifying research articles that contained information about interventions that utilized any form of mHealth like mobile applications, SMS, telephone calls for enhancing public private mix in Tuberculosis. The following terms were used to determine the eligibility of the studies: Articles that were related to the following three key terms were searched from the aforementioned databases. 'mobile health', 'public private mix' and 'Tuberculosis'. Each word was entered as a key word in Google scholar, ScienceDirect, IEEE Xplore and PubMed databases to identify relevant articles relevant to our study. The Boolean search was used to capture articles related to each single main concept using union ('OR') and the intersection ('AND') of the key concepts to focus on the main objective of this review. The bibliography/reference lists of the included studies were also screened to get more studies for inclusion in the study. The results from the search query from the four databases (Google Scholar, Pubmed, IEEE Xplore and ScienceDirect) were uploaded in the EndNote X7 Reference manager (Thomson Reuters, Philadelphia, PA, USA) and were independently assessed for inclusion based on title, abstract and full text. Divergent opinions about inclusion and exclusion of studies were discussed among the authors until a general consensus was reached

Table 1
Characteristics of the included studies.

Author and Year	Study design/Method/ location	mHealth Intervention	Objective	Primary outcome	Effect	Key Findings
Velayutham et al., 2015	A Pilot Study that involved private practitioners from three TB units in India who were given a demo of using the app to notify TB cases for a period of 6 months. *Study duration*: 1 year *Participants*: 184	• A TB notification Voice based application (MITUN-Mobile interface TB Notification). Private medical practitioners registered in the system and were provided with a designated number where they would call and give the details of the TB cases following the voice prompts	To determine the usefulness and feasibility of Mobile Interface in TB notification (MITUN) voice based system for the notification of TB cases by private medical Practitioners	Utilization and Feasibility	• Of the 184 private medical doctors who participated in the study, only 11 (6%) practitioners used the application. • Of the 155 TB cases that were diagnosed, only 15 (10%) were notified through MITUN.	Suboptimal performance with 6% utilization • Lack of time to use the system • Technical/operational challenges • Busy phone line/call interruptions
Thu et al., 2020	A cohort study that involved the analysis of routine surveillance data of patients aged 15 and above attending the OPD for a period of six months in Vietnam *Study duration*: 6 months *Participants*: 110 TB cases	• A mobile application was used to reduce dropout in the care cascade and to enhance follow up care by community health workers	To evaluate the performance of an innovative Private sector engagement model by tracking the cascade of TB care among individuals attending Haiphong International General Hospital (HIGH)	Utilization	• Of the 299 patients who had suggestive TB symptoms, 110 total cases were notified through the application. Of the diagnosed cases, 105 (95%) were initiated on treatment and 97 (93%) had a successful treatment outcome	• The Mobile app enabled the notification of every TB case diagnosed by alerting the health care system to provide follow up care to patients thus reducing the initiation and completion
Lestari et al., 2017	A Pilot study among private practitioners in Bandung city, Indonesia *Study duration*: 6 months *Participants*: 12 private practitioners and 36 TB symptomatic patients	• A mobile app for the notification of TB cases that enabled referral and report back system that utilized simplified versions of the NTP forms	To evaluate the feasibility of the intervention package to increase TB case detection and notification rates among private practitioners in Indonesia	Feasibility and Acceptability	• Of the 12 Private practitioners who successfully installed the app, only five (41.6%) registered patients with TB symptoms and cases into the app. • 36 patients with TB symptoms were identified and 17 were confirmed TB positive.	• Application was acceptable and feasible to enable notification of cases.
Choun et al., 2017	A Descriptive study involving following up of TB patients referred to peripheral health facilities in Cambodia *Study duration*: 10 months *Participants*: 109 referred TB patients	• Telephone calls were made to contact patients three days after having been referred to ensure that they reached the peripheral health facility	To assess if tracking of TB patients referred to peripheral health facilities using mobile phone technology can reduce Lost to Contact after referral (LTCR)	Feasibility	• Out of 109 TB patients referred to the peripheral unit, 107 (98%) had access to a phone of which 103 (97%) were contacted directly and placed on continued TB support. • All participants could be traced compared to previous years where 16–69% of the referred patients were missed	• High retention of the referred patients from the tertiary hospital settings
Khan et al., 2012	An Impact evaluation study of mass communication strategy to encourage people with 2 weeks or more productive cough to seek care at private facilities in Pakistan *Study duration*: 10 months *Participants*: 2416 TB cases notified	• A mobile phone app linked to conditional cash transfers were used by screeners to collect, submit and retrieve data • Screeners utilized telephone calls to follow up the identified TB patients who never initiated TB treatment.	To measure the effect of a multifaceted TB case detection strategy in Pakistan	Usability	• Of the 388,196 individuals screened, 2416 cases were detected and notified via the NTP reporting center. This implies a 2.21 times increase in case notification (95% CI 1.93–2.53) compared to the control area where the number reduced by 9%.	• Increase in TB case notification in the intervention group compared to the control area.
Mohammed, Glennerster and Khan, 2016	A randomized Control Trial at TB treatment Facilities in Karachi Pakistan *Study duration*: 3 years *Participants*: 2207 newly diagnosed TB patients	• A two way scheduled SMS reminders (Zindagi SMS), patient responds back through an SMS or an unbilled phone call to indicate that a patient has taken medication	To measure the impact of *Zindagi SMS*, a two-way SMS reminder system, on treatment success of people with drug-sensitive TB.	Clinically recorded treatment success	• No significant difference between the *Zindagi SMS group and the* control group for clinically recorded treatment success (719 or 83% vs. 903 or 83%, respectively, $p = 0.782$).	• No significant difference between the SMS group and the control group
Chadha et al., 2017	A pilot study among the rural healthcare providers (RHCPs) in India	• A ComCare Mobile application for rural health care providers to refer presumptive TB	To determine the feasibility and yield of presumptive TB case referrals by RHCPs	Feasibility	• 1578 presumptive TB referrals of which 1056 were referred using the mobile app compared to	• The Rural Health Care Practitioners using mobile technology referred nearly nine

(*continued on next page*)

Table 1 (*continued*)

Author and Year	Study design/Method/ location	mHealth Intervention	Objective	Primary outcome	Effect	Key Findings
	Study duration: 3 months *Participants*: 30 healthcare providers and 127 TB cases	cases to the nearest microscopy center	using mHealth technology.		522 cases referred by those who never had the app. • Of the total 194 cases that were diagnosed, the number of mRHCP referrals was 127 (65.5%, four TB cases per RHCP) compared 64 cases (34.5%, 0.5 TB cases per RHCP) referred by their counter parts who never used the app.	times more presumptive TB cases than those without the technology • Reduced the amount of time taken for diagnosis and treatment initiation.
Pande et al., 2017	A pilot study among clinicians at a private hospital in Manipal India *Study duration*: 1 month *Participants*: 101 clinicians	• Learn TB Mobile app among private sector academic clinicians in Kasturba hospital, India	To understand the user experience and acceptability of a smart phone application *LearnTB* among private sector academic clinicians.	Experiences and acceptability	• 101 clinicians received the mobile app on iPads for use. • High user experience of the learnTB application with the mean score = 94.4 (92.07–96.76) with a significantly correlated perceived ease of use (PEU) to perceived usefulness (PU) (r = 0.466, $P < 0.0001$). • The app was perceived to have potential to promote good clinical practices (QR = 5.23 (1.35–20.29); P = 0.016).	• High user experience among the clinicians • There was a significant correlation between perceived ease of use (PEU) and perceived usefulness (PU)
Ali et al., 2016	A pilot study aimed at utilizing digital scanning among the District field workers in Pakistan *Study duration*: 3 months *Participants*: 4 field workers and 122 patients records retrieved and analyzed	• ODK (Open data Kit) scan for data collection and management	To reduce the time and resources spent on TB data collection by improving data collection and digitization process and reducing on manual data entry	Experiences	• Significant time reduction in data aggregation, and transfer activities with the 99.2% of multiple choice fill in bubble responses and 79.4% of numerical digit responses recognized correctly.	Despite the significant time reduction in data aggregation and transfer activities, form filling and verification consumed more time

2.4. Study selection criteria

Studies were included in the review if they met the following criteria.

i. Peer reviewed
ii. Full research papers
iii. Empirical research (qualitative and quantitative)
iv. Clearly explained research methods
v. Explicitly described mHealth technologies for enhancing Public Private Mix in TB care or the mHealth interventions were discussed in the methods section.
vi. The effectiveness in terms of preliminary impact
vii. Explicitly described outcomes on TB care
viii. Published between 1st January 2003 and 31th December 2020
ix. Study available in English language.

Criteria 1–4 were considered to ensure the reporting of original research and high quality work. Criteria 5 was included to ensure that the paper reported on mHealth interventions for enhancing PPM mix in TB care. Our definition of mHealth includes the utilization of basic functionalities of mobile phones for health-related purposes. This includes functionalities such as SMS reminders that can run on basic phones, which, compared to smart phones have a wider adoption in TB burdened countries. This review defines "mHealth" as any medical or public health practice which capitalizes on a mobile phone's core utility of voice and short messaging services (SMS) as well as more complex functionalities and applications including Global Positioning systems (GPS), General packet radio service (GPRS) and Bluetooth technology (WHO, 2011). Interventions that were delivered using any form of mHealth like mobile applications, SMS, telephone calls, GPS were included in this review. Criteria 3, 4 and 6 were considered to enable quality of evidence assessment. Criteria 6&7 were considered to assess the reported TB management outcomes. Criteria 8 was considered because the PPM was recommended by World Health Organization in 2003 (Uplekar, 2003), therefore the inclusion of articles before 2003 would not report the actual experiences.

2.5. Exclusion criteria

The studies were excluded if they did not focus on mHealth interventions for Public Private Mix in TB care, carried out before 2003. Included studies were examined to ensure that they reported the outcomes of the mHealth intervention, thus protocols, reviews, formative/exploratory studies, editorials; letters, position papers were not included. All the studies were included irrespective of the study design and geographical location in order to expand our search.

2.6. Data extraction and analysis

The following characteristics were extracted from the included studies: study setting, study design, mHealth intervention used and the study duration as shown in Table 1, and the description of the identified mHealth interventions' strength and weaknesses are listed in Table 2.

Of the nine studies included, three were conducted in India, three in

Table 2
Description of the identified mHealth interventions' strength and weaknesses.

Author	Intervention	Strength	Weakness
Voice based system for TB case notification			
Velayutham et al., 2015	A mobile interface in Tuberculosis notification (MITUN) voice based system for notifying TB cases among the private healthcare providers.	Based on the VoiceNet architecture that allows the usability on low-end mobile phones	• System complexity resulted into non usability • Long period of time for case notification • Poor system configuration that resulted into delays in notifying cases due to busy phone lines
Mobile applications			
Thu et al., 2020	A mobile application for enhancing patient follow up by community health workers	• Notification of every diagnosed case by alerting the healthcare system and community health workers to proactively track and follow up patients	• The operation of the app are not discussed (how case notification was done, how the alerts for follow up were done) • Doesn't describe the software framework on which the app was developed
Lestari et al., 2017	A referral and reporting back system mobile phone app for case notification	• Utilized simplified version of NTP forms for case notification • Secure centralized server for inputted information • User registration and account creation	• Doesn't describe the software framework on which the app was developed • Not standalone (requires internet to access) • No reminder system to alert the private provider if the patient doesn't complete their treatment follow-up
Chadha et al., 2017	ComCare mobile application for assisting rural health care providers (RHCPs) to identify and refer presumptive TB patients to the nearest microscopy Centre	• Generates SMS reminders for patients to adhere to referral • Assists healthcare providers in providing guidance and counselling to patients • Uses multimedia educational messages for RHCPs	• Not standalone (requires internet to access) • Doesn't describe the software framework on which the app was developed
Khan et al., 2012	A mobile phone based interactive application for community lay people to screen patients for TB in private clinics.	• The app allowed scheduling for sputum collection, initiation of treatment, clinic visits and drug dispersal • Allows data entry and retrieval • Secure centralized server for inputted information	• Doesn't describe the software framework on which the app was developed
Pande et al., 2017	The LearnTB mobile app for educating the private sector clinicians about definition, diagnosis, treatment, management and counselling practices for TB	• Educate private sector clinicians in TB care	• Not standalone (requires internet to access) • Doesn't describe the software framework on which the app was developed
Ali et al., 2016	An android based smartphone application that utilizes an inbuilt camera to capture an image of a scan compatible paper form that is processed through image processing algorithms to map the captured image to its corresponding template	• Significant time reduction in data aggregation and transfer activities	• Decreased digital data quality • Long period of time for data entry and verification
Telephone calls			
Choun et al., 2017	Mobile phone tracking of the referred patients' through telephone calls. Health staff made telephone calls to the referred patients to ascertain whether they had reached the designated peripheral health facility where they were referred	Utilized simple phone calls to follow up the referred patients	• Unavailability of telephones numbers (Calls not reached) • Possibility of wrong telephone numbers • Poor connectivity
SMS			
(Mohammed, Glennerster and Khan, 2016)	Zindagi SMS reminders among the newly diagnosed patients. This used two-way reminders for encourage patients to engage with the reminders. Patients were expected to reply by sending either a text message or an unbilled phone call as a proof that they have taken medication.	Utilizes SMS technology for reminding patients to adhere to medication.	• Doesn't favor those unable to read • Poor connectivity

Pakistan, one in Vietnam, one in Indonesia, and one in Cambodia. No study reported the usability of mHealth intervention for PPM in TB was identified from Africa. The differences in the studies for inclusion were reviewed and checked to ascertain the compliance to the inclusion criteria.

2.7. Quality assessment

mHealth evidence reporting and assessment (mERA) checklist (Agarwal et al., 2016) was used to assess the quality of the identified mHealth interventions. This checklist consists of 16 key items for reporting the evidence of mHealth interventions by addressing their content, context and several implementation features. The checklist was used because it offers guidance on the development of complete and transparent reports on studies that evaluate the usability, feasibility and effectiveness of mHealth interventions (Karim et al., 2020).

In addition, a validated checklist for evaluating studies with diverse designs by Sirriyeh and colleagues was used to assess the quality of the included studies. Each paper was assessed against 14 points on the checklist if the study was either qualitative or quantitative and 16 points on the checklist if it used mixed methods (Sirriyeh et al., 2012). A percentage score to measure quality was calculated for each paper, studies that scored less than 50% were considered poor quality, and those that scored 50% to 70% were considered Moderate and those greater than 70% were considered high quality.

3. Results

3.1. Search results

Fig. 1 below shows the database search results, screening, exclusion and final inclusion in the study. The studies described and identified different mHealth interventions implemented in five countries where the studies were carried out (India, Vietnam, Indonesia, Cambodia and Pakistan).

3.2. Quality of studies

All the papers that were included in this review were of moderate or high quality ranging from 62.5% (Ali et al., 2016) to 83.3% (Pande et al., 2017).

3.3. mHealth essential quality assessment

The mERA criteria (Agarwal et al., 2016) guided the assessment of quality of mHealth interventions included in this review where all the included studies met between 56.25% -93.75% of the mERA criteria. All the included studies documented the availability of infrastructure to support the technology, the technology platform on which the mHealth intervention would run, were compliant with the national guidelines and were delivered as planned (fidelity) as shown in Figs. 2 and 3 below.

All the studies reported mHealth interventions that:

i) Were integrated within the existing health information systems
ii) Clearly documented the mode of intervention delivery and the adoption inputs necessary to implement the mHealth solution.
iii) Clearly described how the intervention was adopted (contextual adoptability),

Four studies (Lestari et al., 2017; Khan et al., 2012; Chadha et al., 2017; Pande et al., 2017) described data security protocols. Five studies (Velayutham et al., 2015; Choun et al., 2017; Khan et al., 2012; Chadha et al., 2017; Ali et al., 2016) described support for replicability. Five studies documented limitation to scale (Velayutham et al., 2015; Choun et al., 2017; Lestari et al., 2017; Chadha et al., 2017; Ali et al., 2016). Five studies reported feedback from users (Velayutham et al., 2015; Choun et al., 2017; Thu et al., 2020; Lestari et al., 2017; Ali et al., 2016). Six studies (Velayutham et al., 2015; Lestari et al., 2017; Khan et al.,

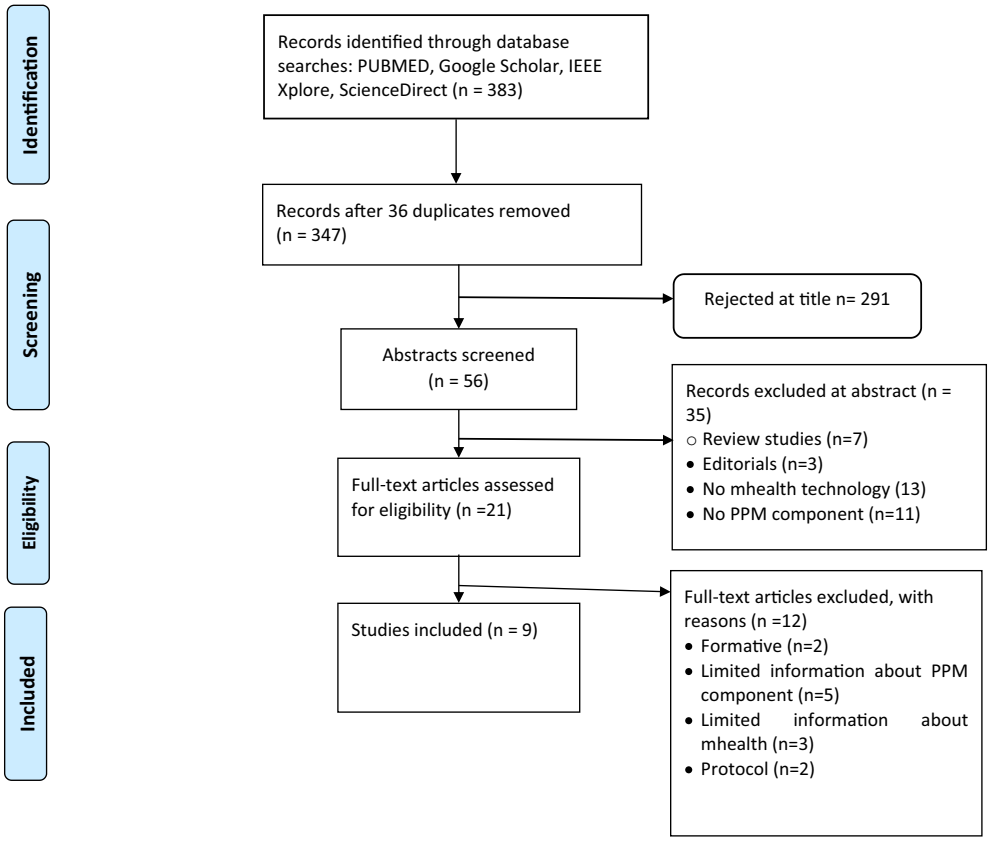

Fig. 1. Flow diagram for the selected studies.

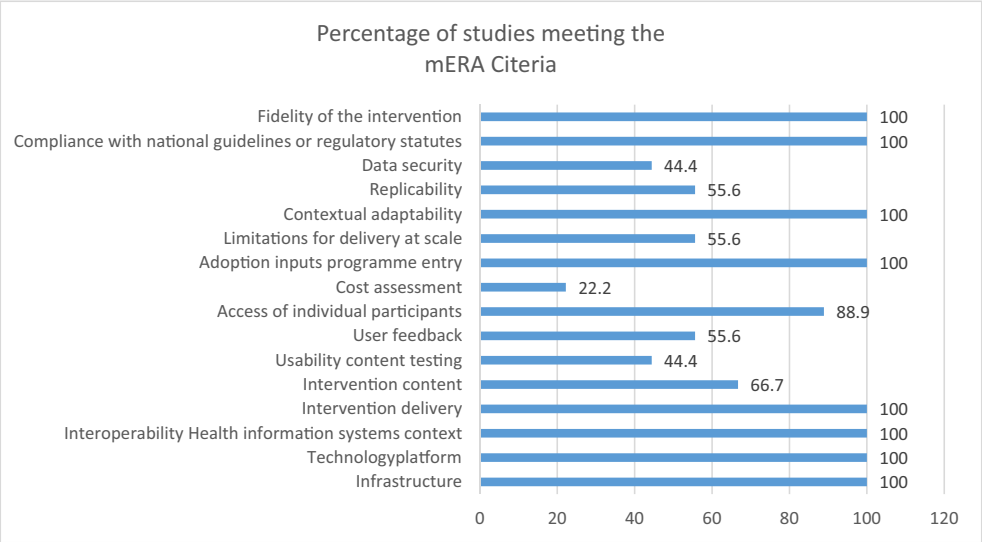

Fig. 2. The percentage of studies meeting the mERA criteria.
Showing the percentage of studies meeting the mERA criteria.

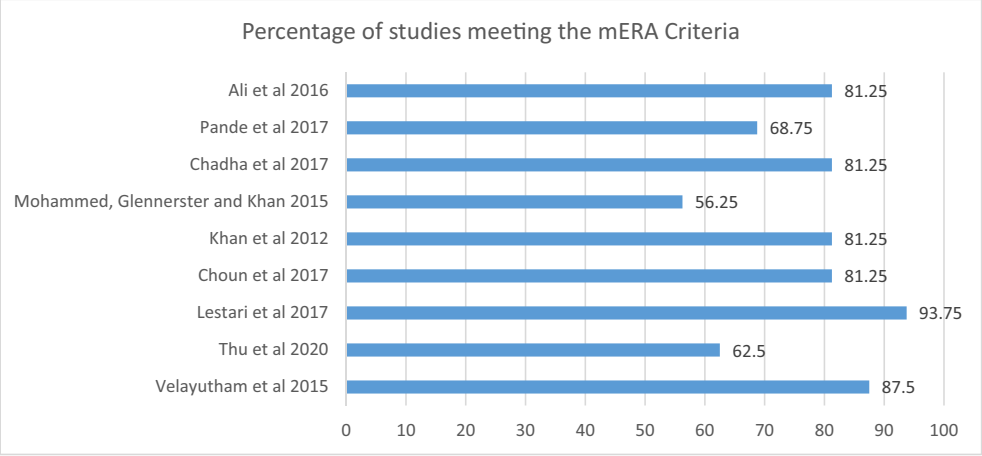

Fig. 3. Percentage of studies meeting the mERA criteria.
Showing the studies meeting the mERA criteria.

2012; Chadha et al., 2017; Pande et al., 2017; Ali et al., 2016) reported details about the content of the intervention (Intervention Content). Four studies (Velayutham et al., 2015; Thu et al., 2020; Lestari et al., 2017; Khan et al., 2012) documented the usability/content testing with the participants. Only two studies reported the cost assessment of the intervention (Lestari et al., 2017; Choun et al., 2017), only one study does not report the access of individual participants (Thu et al., 2020).

3.4. *The application of mHealth for PPM in TB care*

Details of all the studies are indicated in Table 1 above.

3.4.1. *TB screening*

An impact evaluation study that involved 54 private family medical clinics was carried out in Karachi Pakistan by Khan and colleagues (Khan et al., 2012), reported the incentivization and training of community lay people to screen patients in the private clinics. This was done using a mobile phone based interactive algorithm that utilized electronic forms that was linked to a conditional cash transfer for assessing patients and visitors in the clinics waiting areas and the outpatients departments. The software operated on any Java enabled phone with General Packet Radio Service (GPRS) and allowed the entry and retrieval of data to a centralized database. The app also allowed scheduling for sputum collection, initiation of treatment, clinic visits and drug dispersal.

3.4.2. *TB case notification*

Five studies (Thu et al., 2020; Lestari et al., 2017; Chadha et al., 2017; Velayutham et al., 2015; Khan et al., 2012) reported the utilization of mobile apps for TB case notification.

Thu and colleagues implemented an innovative public private mix model in Vietnam by utilizing a mobile phone based case notification application to reduce the dropout in the TB care cascade and enhance patient follow up by community health workers (Thu et al., 2020). The study reported the utilization of the mobile application for notification of every diagnosed case, which enabled the healthcare system and providers to proactively track and provide follow up care to the patients thus reducing the gaps in treatment initiation and completion.

A pilot study (Velayutham et al., 2015) that was conducted in Chennai India reported the utilization of a voice based notification system (Mobile Interface in TB notification (MITUN)) for notifying TB cases among the private healthcare providers. Designated telephone lines through which the private healthcare workers would call on to

interact with the interactive voice response system (IVRS) to notify a case were established. The study reported failure to use MITUN due to technical problems such as busy telephone phone line and call interruption, and lack of time to hold on the call.

3.4.3. Treatment adherence

One randomized control trial (Mohammed et al., 2016) that was conducted in Karachi Pakistan utilized Zindagi SMS reminders among the newly diagnosed TB patients. This used two-way reminders to encourage patients to engage with the reminders. Daily SMS reminders were sent to enrolled patients to take their medication and they were expected to reply by sending either a text message or an unbilled phone call as a proof that they have taken medication. The study reported no significant difference in treatment outcomes between the SMS intervention and the control group.

3.4.4. Data collection and management

A pilot study was carried out in Pakistan by Ali and colleagues to implement a mobile phone based application that was aimed at reducing the amount of time and resources spent on TB data collection by digitizing data collection process and reducing reliance on manual data entry in the public–private mix model of the TB control programme of Pakistan. The app utilizes the device's inbuilt camera to capture an image of a scan compatible paper form that is processed by the app to map the captured image to its corresponding template (Ali et al., 2016).

3.4.5. Patient referral and followup

In another study that was conducted in Khunti district, Jharkhand state, India by Chadha and colleagues, ComCare mobile application was developed to assist rural health care providers (RHCPs) to identify and refer presumptive TB patients to the nearest microscopy center. The app had different interfaces for the RHCPs, laboratory technicians and the supervisors who were trained to use the application. When a presumptive case was identified by the RHCPs, they would be referred to a TB microscopy center where patients' details were entered using the available options in the mobile app. The supervisors would view this information on their mobile phones and then the lab technicians would transmit results to the presumptive cases/patients on their mobile phones via inbuilt text messages in the Comcare application. In case the patient fails to visit the TB microscopy center after getting the results, the application automatically sends SMS reminders to the patient about visiting the microscopy center. The app also has multimedia content for RHCPs for counselling and guiding the patients. The app operated on android mobile phones and was installed on the RHCPs mobile phones (Chadha et al., 2017).

A descriptive study was carried out in Cambodia by Choun and colleagues to assess if tracking of TB patients referred to peripheral health facilities using mobile phone technology can reduce Lost to Contact after Referral (LTCR) (Choun et al., 2017). The study implemented mobile phone tracking of the referred patients' through telephone calls. Health staff made telephone calls to the referred patients to ascertain whether they had reached the designated peripheral health facility where they were referred.

In another study carried by Lestari and colleagues in Bandung City, Indonesia, a referral and reporting back system mobile phone application was developed (Lestari et al., 2017). The app was composed of simplified NTP forms where patients' identity, symptoms, diagnostic examinations, type of TB and treatment were inputted. The app had a centralized server where the inputted data was sent and was monitored by the research staff.

Khan et al., 2012 also reported utilizing telephone calls by screeners to follow-up identified TB patients who never initiated TB treatment in Pakistan. Screeners were required to attempt at least three phone calls to the identified TB cases that never initiated treatment (those intending to default) in addition to two home visits to follow up these patients. However, the study doesn't report the efficacy of these phone calls on health outcomes of the identified TB patients that were being followed up.

3.4.6. Education

Pande and colleagues implemented the LearnTB mobile app for educating private sector clinicians in India (Pande et al., 2017). The app was developed to educate Indian clinicians about the available definition, diagnosis, treatment and management practices of TB. The app was made of sections for clinicians to click to read and get more information. One hundred one (101) clinicians received the mobile app on iPads for use and were assessed to understand their experiences and the feasibility and acceptability of the application.

4. Discussion

4.1. Summary of evidence

Our review aimed at summarizing the published evidence on the utilization and effectiveness of mHealth interventions for public private mix in TB care from literature. This was through online database search for peer-reviewed literature about mHealth interventions for PPM in TB care. Studies that discussed the utilization of mHealth interventions for implementing PPM in TB care were included. Nine studies met the inclusion criteria and were analyzed for review. Several mHealth interventions identified by this review include mobile applications used for TB case notification (Khan et al., 2012; Thu et al., 2020; Chadha et al., 2017; Velayutham et al., 2015 & Lestari et al., 2017), educating clinicians about TB (Pande et al., 2017) and data collection and management (Ali et al., 2016). Telephone calls for patients follow up (Choun et al., 2017) and SMS reminders (Mohammed et al., 2016) for Medication adherence. This resulted into high user experience (Pande et al., 2017), significant time reduction in data aggregation (Ali et al., 2016), increased case notification (Khan et al., 2012) and referrals (Chadha et al., 2017) and proactive tracking and provision of follow up care hence reduced treatment and completion gaps (Thu et al., 2020). Although various mHealth technologies have been utilized in enhancing public private mix, technical and operational challenges encountered by the users can hinder the technology usability as evidenced in India (Velayutham et al., 2015) where system complexity resulted into non usability.

The latest WHO Roadmap for PPM (WHO, 2018b) emphasizes harnessing the power of digital technologies in order to attain 100% systematic engagement of all non-state providers in TB care by 2030–2035. There is need for additional practical evidence from the pragmatic implementation of several digital interventions to enhance the translation of findings into local practice (Ngwatu et al., 2018). Our review identified several mHealth interventions utilized in public private mix for TB care, which include mobile apps, SMS messages, telephone calls, and voice based notification systems. These interventions have the potential to facilitate better patient outcomes compared to the routine standard of care.

None of the identified studies reported the software framework (an abstraction in which the software providing generic functionality can be selectively changed by additional user written code thus providing application-specific software) on which the implemented mobile apps were developed. This limits replication and implementation of the software architecture for applications with similar characteristics and provision of support for large-scale reuse of the interventions (Fayad, 2001, Fontoura et al., 2000), which could have contributed to optimal usability since several factors could have been missed during the intervention development. There is need for developers and researchers to ensure the implementation of interventions that allow replication and reuse on a larger scale implementation.

None of the reviewed studies document behavioral theoretical frameworks on which these interventions were developed.). Interventions based on behavioral theory are efficacious in changing

health behaviors (Karim et al., 2020; Hagger and Weed, 2019), and yield better health outcomes (Cho et al., 2018; Vandelanotte et al., 2016). Lack of theoretically founded mHealth interventions has been a major contributor to small effect sizes. The implementation of mHealth interventions based on behavioral theories has been recommended as a key step for mHealth research design (Glanz and Bishop, 2010). There is an urgent need for theory-based mHealth interventions for enhancing PPM.

Although a mobile application was reported to have increased case detection by Khan et al., 2012, it is rather hard to attribute treatment success and evaluate the actual contribution of the mHealth app as far as case notification is concerned. This is because the study was combined with other interventions (mass media campaigns that involved billboards, cable television adverts, posters, banners and flyers) for encouraging patients to seek medical attention from study sites (Denkinger et al., 2013). In addition, although Thu et al. (2020) also reports that the mobile app reduced the dropout rate in the cascade of care, the study does not clearly report the design features (software architecture) of the app, which limits comparability. It is pertinent for researchers to state and define the parameters that were used to design the application, its key functionalities to enhance the clear assessment of the intervention effectiveness especially in instances where mobile apps are combined with several other interventions. This will aid in understanding the effectiveness of the implemented mHealth technology.

On the other hand, the utilization of community lay people to screen patients for TB, might result into potential status disclosure. This might result into stigma, discrimination and discomfort (Mhode and Nyamhanga, 2016) among patients who might not feel comfortable about their status being known especially when the community lay workers come from the same village as the patients (Rachlis et al., 2016). Patients are more likely to confide in trained healthcare workers compared to lay people since they are not trained in confidentiality issues (Geldsetzer et al., 2017). Future mHealth intervention implementers must ensure that the confidentiality and privacy of patients is prioritized. Security and privacy are key concerns in mHealth (Whittaker, 2012) and must be carefully addressed for patients to trust it.

Our review noted that the utilization of telephone calls enabled the referred patients to reach the peripheral units of referral in Cambodia (Choun et al., 2017) which resulted into high retention of TB patients. The utilization of telephone follow up calls has been reported somewhere else (Houser et al., 2013) and were associated with satisfaction with care among primary care patients after the ambulatory care visit in USA. Telephone calls were also found to be a cost effective strategy for provision of timely comfort or referral where needed among older patients seeking emergency department service after being discharged from the hospital (Lewis et al., 2017). Our review however noted that voice based notifications (Velayutham et al., 2015) on the other hand did not yield significant results due to both technical and operation challenges encountered on the side of the healthcare workers (busy phone line or call interruptions). The system required about five minutes to notify a single TB case, which is rather a very long time especially for healthcare workers to notify a single case. Such technical issues frustrate the usability and acceptability of the system among the users, which in the end result into the abandonment of the intervention. Using such a system in an already overwhelmed health sector with alarming uneven doctor-patient ratio especially in low resource settings overburdens the service provision efforts. Successful implementation of voice-based systems for case notification requires hiring specific staff for reporting the cases to lessen the burden from the healthcare workers.

The development of mHealth interventions requires the restructuring of the system architecture to ensure that simpler, faster and easy to use interventions (Uplekar et al., 2016) aimed at easing the work of health care workers are developed. Interventions that are perceived to be easy to use can result into sustained use (Opoku et al., 2017) thus better health outcomes. The utilization of user centered approaches that involve studying the user behaviors, requirements, characteristics, needs and skills at each phase of the design (Wever et al., 2008) is crucial in facilitating the acceptability of the developed prototype among the system end users (Goold et al., 2006).

Our review found no significant impact of SMS messages on TB medication adherence (Mohammed et al., 2016), which has also been reported in China (Liu et al., 2015). This however, is in contrast to findings from three meta-analyses (Wald et al., 2015; Mbuagbaw et al., 2013; Finitsis et al., 2014) and one randomized trial (Musiimenta et al., 2018), which on the other hand. report improved ART medication adherence. To ensure positive results, designing and implementation of SMS interventions for TB medication adherence should consider various factors like literacy levels, the duration on treatment since SMS messages are associated to supporting self-administered treatment compared to DOTs (Ngwatu et al., 2018).

Although the review indicates that mHealth technologies have been utilized in fostering public private mix for TB care, their utilization and implementation in Africa remains unknown, yet most countries in Africa still grapple with a high number of TB cases. Research utilizing mHealth for PPM in TB care in Africa is limited yet Africa still struggles with high TB disease prevalence and incidence. Africa contributes to 25% of the global TB cases (WHO, 2020). Thus leaving a research gap about understanding how mHealth is utilized to engage the private sector in TB care especially in African settings. This implies that there is need for investigation to understand the acceptability, feasibility and the efficacy of mHealth technologies for PPM in TB care in Africa since factors that affect/influence the adoption of interventions in different economic settings might differ. Mobile health technology might be helpful in identifying the referred patients who do not present for treatment (Islam et al., 2015), help in reducing the time spent at health facilities (Tumuhimbise et al., 2020). In addition, mHealth technologies are acceptable and affordable alternative approaches for health service in settings where face to face approaches are difficult (Musiimenta et al., 2020; Musiimenta et al., 2021) and monitoring TB medication adherence (Musiimenta et al., 2019). The increased penetration of mobile phone technology and internet usage in Africa (GSMA, 2017) and developing countries offers a strong scientific premise for the implementation of mHealth technologies for enhancing public private mix in TB care (Uplekar et al., 2016).

Our review highlights the lack of impact efficacy studies documenting how these mHealth technologies have been effective in enhancing PPM for TB care. Of the included studies, seven were pilot studies (Thu et al., 2020; Chadha et al., 2017; Velayutham et al., 2015; Lestari et al., 2017; Pande et al., 2017; Choun et al., 2017; Ali et al., 2016). Impact efficacy studies aimed at assessing the effectiveness of mHealth technologies for PPM in TB care would help in narrowing the knowledge gap about several mHealth technologies.

4.2. Strength and limitations

To the best of our knowledge, our scoping review is the first to consider studies that utilized mHealth interventions for public private mix in TB care. Evidence from the identified mHealth interventions contributes to the body of knowledge to the successful implementation of public private mix models for TB care and streamlining clear mechanisms for engaging the private health facilities in TB care. In addition, the review provides guidance on future improvements of these interventions among the current policy makers and implementers.

Nevertheless, our review is not without limitations. First, the review focused on mHealth interventions implemented in public private mix settings. Therefore, mHealth interventions for TB care implemented exclusively in public sector settings were not included which might have changed the findings. Secondly, in spite of the broad search by the investigator, only nine studies were selected for review. Therefore, the interpretation of the study findings should be done with this regard. Lastly, the review only included studies published in English because it's the only International language that the investigator understands, which

implies that some relevant studies published in languages other than English were missed which could have limited our search thus need for future researchers to consider the involvement of additional languages.

5. Conclusion

In conclusion, our review highlights the prevailing mHealth interventions that have been used to enhance public private mix in TB care. There is some modest promise that mHealth interventions can enhance public private mix for TB by supporting screening and notifying cases, patients' referral and follow up, monitoring TB medication adherence, data management and educating clinicians about TB. mHealth could offer an alternative approach for health services utilization especially in settings where face-to-face approaches are difficult. However, the prevailing evidence is generally weak—for example, of the four studies reviewed in this paper, i) only one study was an RCT which did find any effect of mHealth intervention; ii) the two studies that report good effect had methodological issues i.e. one was an uncontrolled before-and-after study, while the other utilized multiple interventions making it hard to tell whether mHealth was a helpful component; iii) the fourth study was a non-controlled comparison.

There is need for future researchers to utilize robust research designs (such as RCTs) and methodologies based on well-known global frameworks, to develop and implement effective interventions for establishing a robust evidence base for mHealth implementation in enhancing public private mix for Tuberculosis. Future developers should aim at developing simpler, flexible and easy to use applications for users by utilizing user centered approaches that are aimed at involving system user in the design of such interventions. There is need to investigate the acceptability, feasibility and efficacy of mHealth technologies for public private mix in TB care in Africa since factors that affect interventions in different economic settings might differ.

Declaration of competing interest

None.

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Appendix A. Supplementary data

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References

Agarwal, S., LeFevre, A.E., Lee, J., L'Engle, K., Mehl, G., Sinha, C., Labrique, A., 2016. Guidelines for reporting of health interventions using mobile phones: mobile health (mHealth) evidence reporting and assessment (mERA) checklist. bmj 352, i1174. https://doi.org/10.1136/bmj.i1174.

Ali, S.M., Powers, R., Beorse, J., Noor, A., Naureen, F., Anjum, N., Ishaq, M., Aamir, J., Anderson, R., 2016. ODK scan: digitizing data collection and impacting data management processes in Pakistan's tuberculosis control program. Futur. Internet 8 (4), 51. https://doi.org/10.3390/fi8040051.

Alipanah, N., Jarlsberg, L., Miller, C., Linh, N.N., Falzon, D., Jaramillo, E., Nahid, P., 2018. Adherence interventions and outcomes of tuberculosis treatment: a systematic review and meta-analysis of trials and observational studies. PLoS Med. 15 (7), e1002595. https://doi.org/10.1371/journal.pmed.1002595.

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.

Arksey, H., O'Malley, L., 2005. Scoping studies: towards a methodological framework. Int. J. Soc. Res. Methodol. 8 (1), 19–32. https://doi.org/10.1080/1364557032000119616.

Asuquo, A.E., Pokam, B.D.T., Ibeneme, E., Ekpereonne, E., Obot, V., Asuquo, P., 2015. A public–private partnership to reduce tuberculosis burden in Akwa Ibom state, Nigeria. Int. J. Mycobacteriology 4 (2), 143–150. https://doi.org/10.1016/j.ijmyco.2015.04.002.

Chadha, S., Trivedi, A., Nagaraja, S.B., 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.

Cho, Y.M., Lee, S., Islam, S.M.S., Kim, S.Y., 2018. Theories applied to m-health interventions for behavior change in low-and middle-income countries: a systematic review. Telemed. e-Health 24 (10), 727–741. https://doi.org/10.1089/tmj.2017.0249.

Choun, K., Achanta, S., Naik, B., Tripathy, J.P., Thai, S., Lorent, N., Khun, K.E., van Griensven, J., Kumar, A.M., Zachariah, R., 2017. Using mobile phones to ensure that referred tuberculosis patients reach their treatment facilities: a call that makes a difference. BMC Health Serv. Res. 17 (1), 575. https://doi.org/10.1186/s12913-017-2511-x.

Deglise, C., Suggs, L., Odermatt, P., 2012. SMS for disease control: a systematic review of applications in developing countries. J. Telemed. Telecare 18 (5), 273–281. https://doi.org/10.1258/jtt.2012.110810.

Denkinger, C.M., Grenier, J., Stratis, A.K., Akkihal, A., Pant-Pai, N., Pai, M., 2013. Mobile health to improve tuberculosis care and control: a call worth making. Int. J. Tuberc. Lung Dis. 17 (6), 719–727. https://doi.org/10.5588/ijtld.12.0638.

Dewan, P.K., Lal, S., Lonnroth, K., Wares, F., Uplekar, M., Sahu, S., Chauhan, L.S., 2006. Improving tuberculosis control through public-private collaboration in India: literature review. Bmj 332 (7541), 574–578. https://doi.org/10.1136/bmjgh-2018-001018.

Evans, C., Turner, K., Suggs, L.S., Occa, A., Juma, A., Blake, H., 2016. Developing a mHealth intervention to promote uptake of HIV testing among African communities in the UK: a qualitative study. BMC Public Health 16 (1), 656. https://doi.org/10.1186/s12889-016-3580-1.

Fayad, M., 2001, June. E-Frame: A Process-Based Object-Oriented Framework for E-Commerce. In: In International Conference on Internet Computing, 1, pp. 124–128.

Finitsis, D.J., Pellowski, J.A., Johnson, B.T., 2014. Text message intervention designs to promote adherence to antiretroviral therapy (ART): a meta-analysis of randomized controlled trials. PloS one 9 (2), e88166. https://doi.org/10.1371/journal.pone.0088166.

Fontoura, M., Pree, W., Rumpe, B., 2000, June. UML-F: A modeling language for object-oriented frameworks. In: In European Conference on Object-Oriented Programming, pp. 63–82.

Geldsetzer, P., Vaikath, M., De Neve, J.W., Bossert, T.J., Sibandze, S., Mkhwanazi, M., Bärnighausen, T., 2017. Distrusting community health workers with confidential health information: a convergent mixed-methods study in Swaziland. Health Policy Plan. 32 (6), 882–889. https://doi.org/10.1093/heapol/czx036.

Glanz, K., Bishop, D.B., 2010. The role of behavioral science theory in development and implementation of public health interventions. Annu. Rev. Public Health 31, 399–418. https://doi.org/10.1146/annurev.publhealth.012809.103604.

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

gSM Association, 2017. The Mobile Economy Sub-Saharan Africa 2017. GSM Association, London.

GSMA, 2020. The Mobile Economy Sub-Saharan Africa 2020 GSMA.

Hagger, M.S., Weed, M., 2019. DEBATE: do interventions based on behavioral theory work in the real world? Int. J. Behav. Nutr. Phys. Act. 16 (1), 1–10. https://doi.org/10.1186/s12966-019-0795-4.

Houser, S.H., Ray, M.N., Maisiak, R., Panjamapirom, A., Willig, J., Schiff, G.D., English, T., Nevin, C., Berner, E.S., 2013. Telephone follow-up in primary care: can interactive voice response calls work? Stud. Health Technol. Inform 192, 112.

Islam, S., Hirayama, T., Islam, A., Ishikawa, N., Afsana, K., 2015. Treatment referral system for tuberculosis patients in Dhaka, Bangladesh. Public Health Action 5 (4), 236–240. https://doi.org/10.5588/pha.15.0052.

Karim, Hesam, Choobineh, Hamid, Kheradbin, Niloofar, Ravandi, Mohammad Hosseini, Naserpor, Ahmad, Safdari, Reza, 2020. Mobile health applications for improving the sexual health outcomes among adults with chronic diseases: a systematic review. Digital Health 6, 1–15. https://doi.org/10.1177/2055207620906956.

Khan, A.J., Khowaja, S., Khan, F.S., Qazi, F., Lotia, I., Habib, A., Mohammed, S., Khan, U., Amanullah, F., Hussain, H., Becerra, M.C., 2012. Engaging the private sector to increase tuberculosis case detection: an impact evaluation study. Lancet Infect. Dis. 12 (8), 608–616. https://doi.org/10.1016/S1473-3099(12)70116-0.

Lee, Y., Raviglione, M.C., Flahault, A., 2020. Use of digital technology to enhance tuberculosis control: scoping review. J. Med. Internet Res. 22 (2), e15727. https://doi.org/10.2196/15727.

Lei, X., Liu, Q., Escobar, E., Philogene, J., Zhu, H., Wang, Y., Tang, S., 2015. Public–private mix for tuberculosis care and control: a systematic review. Int. J. Infect. Dis. 34, 20–32. https://doi.org/10.1016/j.ijid.2015.02.015.

Lentferink, A.J., Oldenhuis, H.K., de Groot, M., Polstra, L., Velthuijsen, H., van Gemert-Pijnen, J.E., 2017. Key components in eHealth interventions combining self-tracking and persuasive eCoaching to promote a healthier lifestyle: a scoping review. J. Med. Internet Res. 19 (8), e277. https://doi.org/10.2196/jmir.7288.

Lestari, B.W., Arisanti, N., Siregar, A.Y., Sihaloho, E.D., Budiman, G., Hill, P.C., Alisjahbana, B., McAllister, S., 2017. Feasibility study of strengthening the public–private partnership for tuberculosis case detection in Bandung City, Indonesia. BMC Res. Notes 10 (1), 404. https://doi.org/10.1186/s13104-017-2701-y.

Lewis, E., Samperi, S., Boyd-Skinner, C., 2017. Telephone follow-up calls for older patients after hospital discharge. Age Ageing 46 (4), 544–546. https://doi.org/10.1093/ageing/afw251.

Liu, X., Lewis, J.J., Zhang, H., Lu, W., Zhang, S., Zheng, G., Bai, L., Li, J., Li, X., Chen, H., Liu, M., 2015. Effectiveness of electronic reminders to improve medication adherence in tuberculosis patients: a cluster-randomised trial. PLoS Med 12 (9), e1001876. https://doi.org/10.1371/journal.pmed.1001876.

Mbuagbaw, L., van der Kop, M.L., Lester, R.T., Thirumurthy, H., Pop-Eleches, C., Ye, C., Smieja, M., Dolovich, L., Mills, E.J., Thabane, L., 2013. Mobile phone text messages for improving adherence to antiretroviral therapy (ART): an individual patient data meta-analysis of randomised trials. BMJ Open 3 (12). https://doi.org/10.1136/bmjopen-2013-003950.

Mhode, M., Nyamhanga, T., 2016. Experiences and impact of stigma and discrimination among people on antiretroviral therapy in Dar Es Salaam: a qualitative perspective. AIDS Res. Treat. 2016 https://doi.org/10.1155/2016/7925052.

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). https://doi.org/10.1371/journal.pone.0162944.

Musiimenta, A., Atukunda, E.C., Tumuhimbise, W., Pisarski, E.E., Tam, M., Wyatt, M.A., Ware, N.C., Haberer, J.E., 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), e122. https://doi.org/10.2196/mhealth.9031.

Musiimenta, A., Tumuhimbise, W., Mugaba, A.T., Muzoora, C., Armstrong-Hough, M., Bangsberg, D., Davis, J.L., Haberer, J.E., 2019. Digital monitoring technologies could enhance tuberculosis medication adherence in Uganda: mixed methods study. J. Clin. Tuberc. Other Mycobac. Dis. 17, 100119. https://doi.org/10.1016/j.jctube.2019.100119.

Musiimenta, A., Tumuhimbise, W., Mugyenyi, G., Katusiime, J., Atukunda, E.C., Pinkwart, N., 2020. Mobile phone-based multimedia application could improve maternal health in rural southwestern Uganda: mixed methods study. Online J. Public Health Inform. 12 (1) https://doi.org/10.5210/ojphi.v12i1.10557.

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 p.2055207620986296.

Naqvi, S.A., Naseer, M., Kazi, A., Pethani, A., Naeem, I., Zainab, S., Fatmi, Z., 2012. Implementing a public-private mix model for tuberculosis treatment in urban Pakistan: lessons and experiences. Int. J. Tuberc. Lung Dis. 16 (6), 817–821. https://doi.org/10.5588/ijtld.11.0440.

Ngwatu, B.K., Nsengiyumva, N.P., Oxlade, O., Mappin-Kasirer, B., Nguyen, N.L., Jaramillo, E., Falzon, D., Schwartzman, K., 2018. The impact of digital health technologies on tuberculosis treatment: a systematic review. Eur. Respir. J. 51 (1) https://doi.org/10.1183/13993003.01596-2017.

Nwe, T.T., Saw, S., Mon, M.M., van Griensven, J., Zhou, S., Chinnakali, P., Aung, S.T., 2017. Engagement of public and private medical facilities in tuberculosis care in Myanmar: contributions and trends over an eight-year period. Infect. Dis. Poverty 6 (1), 123. https://doi.org/10.1186/s40249-017-0337-8.

Opoku, D., Stephani, V., Quentin, W., 2017. A realist review of mobile phone-based health interventions for non-communicable disease management in sub-Saharan Africa. BMC Med. 15 (1), 1–12. https://doi.org/10.1186/s12916-017-0782-z.

Pande, T., Saravu, K., Temesgen, Z., Seyoum, A., Rai, S., Rao, R., Mahadev, D., Pai, M., Gagnon, M.P., 2017. Evaluating clinicians' user experience and acceptability of LearnTB, a smartphone application for tuberculosis in India. Mhealth 3. https://doi.org/10.21037/mhealth.2017.07.01.

Pew Research Center, 2015. Cell phones in Africa: communication lifeline. http://www.pewglobal.org/2015/04/15/cell-phones-in-africa-communication-lifeline/. WebCite Cache ID 6tjcNGJ61.

Rachlis, B., Naanyu, V., Wachira, J., Genberg, B., Koech, B., Kamene, R., Akinyi, J., Braitstein, P., 2016. Community perceptions of community health workers (CHWs) and their roles in management for HIV, tuberculosis and hypertension in Western Kenya. PloS one 11 (2), e0149412. https://doi.org/10.1371/journal.pone.0149412.

Sirriyeh, R., Lawton, R., Gardner, P., Armitage, G., 2012. Reviewing studies with diverse designs: the development and evaluation of a new tool. J. Eval. Clin. Pract. 18 (4), 746–752. https://doi.org/10.1111/j.1365-2753.2011.01662.x.

Slevin, K.W., Forbes, A., Wells, W., 2014. Public private mix (PPM) models for the sustainability of successful TB control initiatives a working meeting co-convened by USAID and the World Bank. In: Collaboration with the Stop TB Partnership's PPM Subgroup, and Organized with PATH.

Subbaraman, R., de Mondesert, L., Musiimenta, A., Pai, M., Mayer, K.H., Thomas, B.E., Haberer, J., 2018. Digital adherence technologies for the management of tuberculosis therapy: mapping the landscape and research priorities. BMJ Glob. Health 3 (5). https://doi.org/10.1136/bmjgh-2018-001018.

Thu, T.D., Kumar, A., Ramaswamy, G., Htun, T., Van, H.L., Quang, L.V.N., Thu, T.D.T., Codlin, A., Forse, R., Crewsell, J., Thanh, H.N., 2020. An innovative public–private mix model for improving tuberculosis Care in Vietnam: how well are we doing. Trop. Med. Infect. Dis. 5 (1), 26. https://doi.org/10.3390/tropicalmed5010026.

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. J. Fam. Med. Prim. Care 9 (7), 3657. https://doi.org/10.4103/jfmpc.jfmpc_281_20.

Uplekar, M., 2003. Involving private health care providers in delivery of TB care: global strategy. Tuberculosis 83 (1–3), 156–164.

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

Uplekar, M., Atre, S., Wells, W.A., Weil, D., Lopez, R., Migliori, G.B., Raviglione, M., 2016. Mandatory tuberculosis case notification in high tuberculosis-incidence countries: policy and practice. Eur. Respir. J. 48 (6), 1571–1581. https://doi.org/10.1183/13993003.00956-2016.

Vandelanotte, C., Müller, A.M., Short, C.E., Hingle, M., Nathan, N., Williams, S.L., Lopez, M.L., Parekh, S., Maher, C.A., 2016. Past, present, and future of eHealth and mHealth research to improve physical activity and dietary behaviors. J. Nutr. Educ. Behav. 48 (3), 219–228. https://doi.org/10.1016/j.jneb.2015.12.006.

Velayutham, Banurekha, T., B., Nair, D., Thiruvengadam, K., Prashant, S., Kittusami, S., Vijayakumar, H., Chidambaram, M., Shivakumar, S.V.B.Y., Jayabal, L., Jhunjhunwala, A., Swaminathan, S., 2015. The usefulness and feasibility of mobile interface in tuberculosis notification (MITUN) voice based system for notification of tuberculosis by private medical practitioners–a pilot project. PLoS One 10 (9). https://doi.org/10.1371/journal.pone.0138274.

Wald, D.S., Butt, S., Bestwick, J.P., 2015. One-way versus two-way text messaging on improving medication adherence: meta-analysis of randomized trials. Am. J. Med. 128 (10), 1139–e1. https://doi.org/10.1016/j.amjmed.2015.05.035.

Wever, R., Van Kuijk, J., Boks, C., 2008. User-centred design for sustainable behaviour. Int. J. Sustain. Eng. 1 (1), 9–20. https://doi.org/10.1080/19397030802166205.

Whittaker, R., 2012. Issues in mHealth: findings from key informant interviews. J. Med. Internet Res. 14 (5), e129. https://doi.org/10.1109/MC.2016.185.

WHO, 2004. Public-private mix for DOTS: report of the second meeting of the PPM subgroup for DOTS expansion. Geneva: WHO; 2004: Report No WHO/HTM/TB/2004.338. http://whqlibdoc.who.int/hq/2004.

WHO, 2011. In: ORGANISATION, W. H (Ed.), mHealth New Horizons for Health Through Mobile Technologies. Based on the Findings of the Second Global Survey on eHealthGlobal Observatory for eHealth series. eHealth.

WHO, 2020. Tuberculosis [Online]. Available. https://www.who.int/news-room/fact-sheets/detail/tuberculosis. (Accessed 17 October 2020).

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. WHO.

World Health Organization, 2017a. Handbook for the Use of Digital Technologies to Support Tuberculosis Medication Adherence.

World Health Organization, 2017b. Global Tuberculosis Report 2017. World Health Organization, Geneva.

World Health Organization, 2018a. Engaging Private Health Care Providers in TB Care and Prevention: a Landscape Analysis (No. WHO/CDS/TB/2018.33). World Health Organization.

World Health Organization, 2018b. Public–Private Mix for TB Prevention and Care: A Roadmap. World Health Organization, Geneva.

World Health Organization, 2020. Global Tuberculosis Report 2020. (In Global tuberculosis report 2020).