Role of mHealth in the management of Tuberculosis: A new approach to improve adherence

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ABSTRACT
Compliance with Tuberculosis (TB) treatment is essential in enhancing singly and public health as well. Nonadherence may come out with suffering, disease worsening, and mortality and also leads to increased economic burden to the patients. Through this article, we want to explore new ideas to strengthen medication adherence with the assistance of mHealth approaches to monitor and enhance TB patient's medication-taking behavior. DOTs have more success rates in particular parts, whereas its limitations in improving the adherence can be understood in the world health organization End Tuberculosis plan of action. To provide disease and treatment-related education to the patients, mHealth apps should be of educational worth to patients by delivering classified information, which is easily accessible to the patients and caregivers. Hurdles to TB treatment compliance are noteworthy and multiple. Mobile health accounts for an arising field with significant promises to locate barriers, thus enhancing every single individual and community health and health care systems planning.

INTRODUCTION
Compliance to tuberculosis (TB) treatment is essential in enhancing singly and public health as well. As non-adherence may come out with suffering, disease worsening and mortality and also leads to increased economic burden to the patients as the length of the treatment regimen increases and drug resistance develops (Schmidt et al., 2015). Exploring novel approaches in improving adherence is very important with growing non-adherence. Mobile health (mHealth) plays a significant role to develop a standard of living and efficient in health care (Lewis et al., 2012). Even though its prospects in tuberculosis stood unleashed (World Health Organization, 2014) and patient-related mHealth application is deficient in response to the difficulty of real-time scenarios (Denkinger et al., 2013) including the significant setback is lack of ethical evaluations of mHealth interventions (van Gemert-Pinjen et al., 2012). The forethought, performance and assessment of mHealth interventions for Tuberculosis...
sis therapy compliance should be directed by morals as much as by mechanical upheaval (World Health Organization, 2012).

Through this article, we want to explore new ideas to strengthen medication adherence with the assistance of mHealth approaches to monitor and enhance TB patients medication-taking behaviour adherence, set up a framework for contemplating of the central moral subject, especially when mHealth is coordinated with inducements, and sketch a prototype to direct the ethical planning, execution, and assessment of succeeding mHealth interventions for compliance to make it the best as possible (Kay et al., 2011). By doing that, we draw particular attention to the aspects of the noble task and also chances opportunities for moral progress over direct observation of therapy (DOT), WHO guidelines for observing Tuberculosis therapy compliance.

**Tuberculosis and its significance adherence**

Overall 10 million people had TB in 2017, as well as 0.9 million people were living with HIV. Globally TB was the record-breaker of death in 2017 and was a root cause for higher mortality than HIV (World Health Organization, 2015a). In the same year, 1.6 million shot died with TB, conjointly 0.3 million with HIV. On and all, an anticipated 558 000 people susceptible to TB who were resistant to Rifampicin (RR-TB), the virtual front-line medications, among which 82% had multidrug-resistant TB (MDR-TB) in year 2017 (World Health Organization, 2015b).

As per World Health Organization (WHO), the Tuberculosis therapy comprises of a first treatment phase scheme consists of a beginning treatment phase needing a day to day administration of 4 front-line treatment with anti-TB medications for a period of 2 months, under a 4-month continuation phase throughout which 2 day to day medicines are essential. Administering medication three times a week in the two phases is also pragmatic (World Health Organization, 2010). A patient can be named as drug-susceptible one when resistant to the whole front-line medicines. Among multi various Drug-resistant TB forms multidrug-resistant TB and extensively drug-resistant TB well acknowledge (Centers for Disease Control and Prevention, 2016). Surprisingly slight resistant types of DR-TB require two years along with daily medication. Apt therapy is prominent for all forms of TB in alleviating single person morbidity and mortality in tuberculosis patients. Preventing spreading among family and community members is also very significant. Appropriate therapy also hampers the adaptability and acquiring DR-TB. On all sides be it money, be it health, TB costs more by producing severe side effects, extravagant expenditure with low quality of life (World Health Organization, 2013). Treatment given for morbidity, mortality, and spreading of the disease is further influenced and affected by poverty, immune-compromised, and lack of proper health education which is identified in various tuberculosis patients of developing countries (Islam et al., 2011). As the prompt treatment relies partly on good adherence, observing and promoting adherence should be emphasized to safeguard both single individual and public health.

Adapting Good medication compliance is a significant element of WHO’s published 2015 world TB plan of action—the “End TB Strategy.” The first concern of this plan of action requires “reassuring therapy management to assist ill-health persons in tacking medications and also to the course completion, enhancing their cure and adapting the further constraints like drug-resistant” (Islam et al., 2011). This plan of action directs management must be tackled with a patient-specific approach and diplomatic manner and reduces the various barriers to compliance, such as “literacy, psychological, and materialistic needs,” “unfair beliefs and prejudices,” and health-care-related factors (World Health Organization, 2013). To overcome these multiple barriers, supportive therapy monitoring might be automatically sophisticated, extending interventions to educate treatment partners, to impart common significance defence, anticipate and interchange important details and bring awareness in farther distances by using incentives. When it comes to supportive treatment, monitoring of adherence (DOT) is of prime importance. WHO recommends direct addressing of administering anti-Tb drugs in every setting by health care worker as a global level of care. Ethical acceptability necessitates about the introduction of new monitoring techniques that should be compared with DOTS.

**Barriers to Adherence**

DOTs have more success rate in particular parts. In contrast, its limitations in improving the adherence can be understood in world health organization End Tuberculosis plan of action (Islam et al., 2011). Four categories of barriers, such as structural, patient, social, and health care service factors were identified, and they affect the adherence rate differently (Munro et al., 2007). Considering non-adherence to TB as impeding requires enlightenment on all TB relevant factors.

**Structural Factors**

Structural factors which include poverty and Gender have a significant effect on adherence rate; nevertheless, patients are significantly impacted. Penury,
Table 1: Clinical framework where proof reveals that applications might add-on worth to patient supervision

<table>
<thead>
<tr>
<th>Classification of mobile Health App</th>
<th>Example clinical framework where mobile health applications may add-on worth to patient supervision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostics and clinical decision making</td>
<td>Interactive manifestation analyzers can be utilized for extreme situation in parts of restricted accessibility to healthcare system.</td>
</tr>
<tr>
<td>Behavior change interventions through mHealth</td>
<td>Mass Index for overweight patients and advancements in HbA1c for early stage diabetics.</td>
</tr>
<tr>
<td>Digital therapeutics</td>
<td>Monitoring of patient described end results for reappearance of some cancers.</td>
</tr>
<tr>
<td>mHealth apps that deliver disease-related education</td>
<td>Applications might assist way of behaving to gain short-term depletion of Body Mass Index for overweight patients and advancements in HbA1c for early stage diabetics.</td>
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Applications may assist medication compliance in chronic illness along with improved adherence and clinical end results from perioperative care schemes.

Applications might also be utilized to provide disease associated acknowledgment to enhance transmission and to ease better patient choice building in clinical setting.

Applications may assist self-control and mitigation of apprehension where services are inaccessible or where they are unanticipated side effects from prescribed treatments.

Table 2: Potential future value propositions for mHealth apps.

<table>
<thead>
<tr>
<th>Population level value for each category of mHealth app</th>
<th>Broden availability of services through ease of access, reduce inequalities</th>
<th>Cost-effective (low marginal cost, highly scalable, early detection, prevention rather than cure)</th>
<th>Cost-effective (reduce human resource burden on healthcare system by enabling patient driven care)</th>
<th>Improve patient satisfaction through better communication with healthcare providers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostics and clinical decision making apps</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>Behavior change apps</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Digital therapeutic apps</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>Disease-related education apps</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

✓- Yes X-No

majorly while relating to the elements described beneath, could impede medication compliance. For instance, Poor people may remain in ambiguity to choose between work and health as they may find it challenging to meet both ends meet. In developing countries, the average total cost of TB is 39% of yearly described family earnings maximum is 148% (Tanimura et al., 2014).

Based on Gender associated elements also affect medication compliance. Tuberculosis associated unfair beliefs may result in a more significant suppression and even rejection of disease-related treatment amongst females when compared with males, as male and female part among orthodox or below par families can transform to females having the shorter time of, and this condition might end up with significant problems for females to undergo therapy (Johansson et al., 2000).
**Patient Factors**

Patient concerning factors such as patient acknowledging to participate habits impact on adherence and get influenced by lack of memory, understanding regarding TB treatment, general assumptions about the illness as they presume the person is ill only if symptomatic, and alcoholic or on drug use. Furthermore, Side effects of Tuberculosis medication, which comprises weakness, nauseating symptoms, vomiting, icterus, or mortality (Centers for Disease Control and Prevention, 2013), could influence patient enlightenment as these intervene with the patient’s ability to work. When it comes to drug-resistant TB treatment side effects such as psychiatric disorders, impairment of hearing and epileptic seizures may escalate and get worse (Tülay et al., 2006).

**Social Context**

If patients hold strong social assistance by parentage, society, or health care officials could easily overcome structural and personal obstacles to compliance by enhancing acknowledgement and their trust about TB. Nevertheless, deficit assistance or awareness regarding tuberculosis and its therapy in a patient’s house, society, or health care officials, along with factual or supposed unfair beliefs of the patients, can impede compliance (Datiko and Lindtjørn, 2010).

**Health Care Service Factors**

Deficit medication stores, much awaiting time, troublesome timings of service hours, and obstacles in approaching health amenities expose the direct medical costs along with that providing health care service amenities, like postponement of family duties (e.g., Looking after their children needs) and trailing in their work and income. All these collectively contribute to a reduction in adhering to TB treatment (World Bank Open Data, 2015).

**mhealth for Adherence to Tb Treatment**

To rescue from the barriers of medication adherence, mobile health mediation could take a significant part in the removal of challenges and needs to be emphasized. Primarily, a lot of mobile cellular subscriptions per 100 individuals in developing countries is 87 and still expanding (Volpp et al., 2008). Mobile health could potentially prevent DOT-associated journey, subsequently enhancing compliance in rural places. Secondly, mobile health can improve the efficiency of the health care sector in resources constraint areas and specialized health care expertise. Additionally, mHealth can throw light on patient elements contributing non-adherence by easing Nobel including complicated methods of allocating monetary and non-monetary inducements. Here is an example, an analysis of warfarin compliance included pillboxes which made its way up to date on patients into a sweepstake wirelessly, whenever unlocked as per the directed therapy scheme (Volpp et al., 2008), so as reducing the burden for human monitoring and record maintenance. A mobile policy could also assist in overcoming specific strategy of problems of inducement conveyance. Specimens through Kenya (Center for Health Market Innovations, 2012), Malawi (Boccia et al., 2011), and Zambia (Liu et al., 2015) describe the practicality of effective computerized transfer method that removes the burden to move to a bank or rural subject background, majorly enlarging the landing of inducement schemes, reducing the price of inducement conveyance, also making the procedure much more effective. Lastly, actual analysis suggests mobile healths as word of honour for uplifting adherence. The latest research, the foremost to perform a vast and systematic trail in this aspect, arrived at a conclusion stating that the computerized mentions from drug surveillance enhanced Tuberculosis therapy compliance (National Institute for Health and Care Excellence (NIHCE), 2018). Different miniature, proof-of-principle researches had recognized the likely profit of utilizing various types of mobile health for Tuberculosis treatment compliance (Millenson et al., 2017).

**Types of mhealth Techniques**

**Video observation of therapy (VOT)**

Patients accustomed to smartphones to document videos of oneself proceeding every drug dosage, letting health care professionals to outlook the images anyway synchronous or non-synchronously; facial feature identification and moment observation software may be replaced for the necessity of human monitoring.

**Indirect monitoring technology, patient facilitated (IP)**

Following the dosage administration patients either make a free of charge phone calls or drop a message (SMS) to a central server.

**Indirect monitoring technology, device facilitated (ID)**

When the patient unlocks the lid of the container, which consists of medications, an SMS will be wirelessly conveyed to the central server.

**Direct monitoring technology, embedded sensors (DE)**

Whenever the tuberculosis patient administers the TB drugs, that are furnished with a sensor, a wear-
able device stuck to the patient’s body wirelessly transfer the information to the main server.

**Direct monitoring technology, metabolite testing (DM)**

Patients use economic, coded chromatography urine examination strips, that identify medication metabolites in the patients’ urine sample divulging a code; Next patients subsequently drop an SMS along with the system to a main sever.

**The extent of mobile health performances which had manifested Clinical Evidence for Patient Care**

Now a day’s numerous health-related apps are in handy for download from the play store and app store among which small proportion is of clinical use (Semigran et al., 2015). Clinicians and patients have been facing difficulty to select the apps that emphasize patient health care as there are low standard apps as well (Buechi et al., 2017). A latest structured analysis recognized 23 various reported principles for the detection of mobile health applications. However, a lot more apps with which patients are more familiar didn’t perceive as good standard ones by physicians (Ahmed et al., 2018). A health care professional societies and physicians who suggest applications should ensure that the patient’s participation is essential in the choice building method (Byambasuren et al., 2018).

The World Health Organization (WHO) Global Observatory for eHealth (GOH) describes mobile health as therapeutic and community health application assisted by electronic gadgets (Singh et al., 2016). Even though the patients and health care providers are keen into mhealth apps, a lot more direction on utilization which in turn add value to patient health is essential. The value should comprise advancements speed and accuracy of diagnosis, individualized regimens, social change, patient acknowledgement or enhanced approach to already existing treatments like cognitive behavioural therapy (CBT). Our write-up explains the possible merits of mobile health applications for patients.

Perspective to the classification of mobile health applications that are considered in the United Kingdom by the National Institute for Health and Care Excellence (NICE) and the National Health Service (NHS) is by their performance (National Institute for Health and Care Excellence (NIHCE), 2018). The practical categorization is one of the sources for comparisons of different levels of evidence for applications which are used in medical practice. The practical classifications of mobile health applications at most applicable to employ in medical practice are described in the write-up and comprise the succeeding:

1. Assist clinical detection along with choice building in medical decisions;
2. Promote clinical results among standard therapy guidelines via appropriate patient way of behaving changes also improving patient medication-taking behaviour and adherence accompanied by therapy protocol;
3. Behave as an individual computerized health-giving;
4. First and foremost, to furnish disease linked education. In this part, we contemplate the importance of mobile health applications for patients in one and all of the category. Further classification of mobile health applications accompanied by various functions, for example, patient supervision collaboration, disease, drug and wellbeing health information doorway, and the articles which are plotted for recovery are not considered in our analysis.

**Support clinical diagnosis along with choice building**

On and all 50 million people around the globe use application-based self-triage and one of the recent systematic review stated that the utmost often explored a group of diagnostic applications is interactive manifestation analyzer. In US health centres, it was recognized that practical suggestion was specified 80% of the exigency patients in a survey of 23 critical manifestation analyzer applications (Semigran et al., 2015). Nevertheless the accurate diagnostic rate was only 34%, and there was a gradual rise in triage advice appropriateness resulting to 55% of non-exigency patients. Diagnostic manifestation analyzer applications emphasized at particular aetiology like joint pain which arrived at the inaccurate advice (Buechi et al., 2017).

Research work ascertains that symptom checker apps have the possibility of risk and may raise unwanted meetings in the non-exigency surroundings. On the further hand, a lot number of diagnostic applications utilize algorithms to anticipate either pictures or information from a smartphone. With few odds of detective mobile health applications, there is a higher possibility in making significant developments in morbidity and mortality outcomes (Ahmed et al., 2018). The World Health Organization had its voice that computerized diagnostic programmes will be of more substantial help.
in underdeveloped along with developing countries where the advanced clinical approach is difficult (Byambasuren et al., 2018).

Mhealth lead behaviour changes

Apps are potentially sound foundations for assisting behavioural change interference as these apps could involve with an existing plan of action for eradication along with therapy of illness with individualized objective settings, personalized drug dosing indications, and incentivizing (Millenson et al., 2017). Applications which are associated with wearable gadgets which monitor the cardiac rate and also physical activity level which further helps in identifying behaviour modifications and further strategies which mainly targets community perception theory. A recent structured analysis and meta-analysis research revealed that effects of mobile applications are investigated for the improvement in losing weight and monitoring bodily pursuit has shown a drastic reduction in Body Mass Index (BMI) of 0.43kg/m² (95% CI –0.74 to –0.13) with exceedingly slimming noticed while the gadgets were utilized correctly. Upon the usage of behaviour, applications have shown developments in maintaining glycaemic standards in diabetic patients through advanced compliance to standard therapy guidelines (Singh, 2019). Even though the main problem is to attain continuing advancements in the clinical framework along with enduring course results by using the mentioned gadgets are still to be explored. Mobile application established behavioural change interference helps us to locate noncompliance in chronic diseases, which is estimated to be as high as 50% (Zaugg et al., 2018). Amnesia, incomprehension of mechanism of after effects, and impression of ineffectiveness drugs which are considered to be the most common reasons for medication non-adherence can be adequately addressed with the help of a mobile app. One of the recent studies revealed that 762 apps in the play store/app store use behavioural strategies to enhance medication adherence with the help of reminders, occasional alerts and logs (Yin et al., 2019). Interestingly many of the patients gave positive feedback on customized medication regimen details and reminders. But there is another worry with the usage of apps which includes frequent technical difficulties because of glitches, not user-friendly platforms, difficulty in understanding about the application, direction-finding and dosing time table, inflexibility in the mnemonic system.

A structured analysis revealed that a total of 4 out of 805 drug compliance applications which have an association with published evidence of clinical outcomes (Jain et al., 2019). Evidence of top quality among multicenter randomized control trial (RCT) has lately come out representing the capability of app-established interventions to enhance therapy compliance in the supervision of chronic ailments like blood pressure and medical results from inflated perioperative care post elective abdominal operation.

Act as standalone Computerized remedial

Computerized remedial is a word used to relate applications which assist self-regulation of a situation by computing conventional treatment like Cognitive-behavioural therapy. A structured analysis of eight RCT (n=1794) which are anticipating psychological results by using mobile health applications to control depression, prolonged pain acceptance, sleeplessness severity, stress or Post-traumatic stress disorder manifestations conveyed. Differences in effect proportions (d=−0.13 to 1.83; 0.03–1.44) accompanied by greater involvement with upgraded results (Tülay et al., 2006). A renovated meta-analysis from October 2019 revealed 66 RCT. It displayed significantly enhanced medical results in controlling of depression, anxiety, and stress with the help of mobile health applications vs control groups, with related enhancements in standard of living. Prior proof from this survey did not reveal any variance in clinical results with mobile health interventions in head to head trials with face-to-face conveyance of therapies. CBT-established mobile health apps are capable and in a position be used clinically to deal with various types of psychological states and are being examined in clinical trials focusing conditions such as postpartum depression, drug abuse, phobia of heights, and migraine. Early studies data reveals that there is no significantly increment in unwanted events with short-term usage of CBT established computerized remedial (Levin et al., 2019).

Primarily to provide disease-associated education

To provide disease and treatment related education to the patients, mHealth apps should be of educational worth to patients by delivering organized information, which is easily accessible to the patients and caregivers. In one of the recent studies, they randomized the patients with knee joint pain. They encouraged them to utilize either an educational application with related bilateral content or no participation before attending the hospital. The app reveals that there is an improved measure of real disease-associated understanding at clinical attendance by 52% and the perceived knowledge by 22% (Kim et al., 2019). There is a deficit
of randomized controlled trials in anticipating the educational worth of some mobile health interventions; Even though the first proof does subsist to assist the usage of particular educational mobile health interventions for patients with cardiac problems, inflammatory bowel disease (IBD) pediatric forearm fracture, and in patients with breast, colon, lung, prostate, and stomach cancers (Feroz et al., 2017). Disease-associated acknowledgements can also hold on value for patients in rural areas to assist self-control. In majority areas of African countries, mobile network signalling is well built, and there are specific standard schemes in many areas. Out of that, a structured analysis reveals that by delivering educational reminders to African women who are in the postpartum period majority of the common complications can be prevented (Feroz et al., 2017).

The importance of mobile health has to be explored as an important tool for providing therapy-associated awareness in the areas of chronic disease and in oncology, where the treatment protocol is complicated. In these circumstances, mobile health has the full potential to be a trusted resource of appropriate therapy data which significantly improves the quality of life of the patients. A clinical framework where proof reveals that applications might add-on worth to patient supervision were classified in Table 1.

What worth would clinical use of mobile health hold for patients in the subsequent days?

In the upcoming days, it is more likely that evidence-established mobile health applications will be unified into established clinical therapy pathways, to enhance results among existing therapies and elevate approach to particular treatments. There is an immense capability for health information to be extracted from mobile health applications and are utilized to ease early diagnosis disease and aid technology-assisted clinical choice building. We can able to see instances of linked mobile health technologies which can identify situations like atrial fibrillation. Eventually, mHealth technologies will have an essential role to play in equipping patients to control their health through technically enabled care pathways while furnishing additional profits to healthcare delivery programmes. Mhealth helps to provide cost-effective therapy to all the needy population and improves communication with health care professionals. With the help of this technology, time can be saved, and we can detect chronic diseases in early stages which help in better management. Integration with the patient needs and standard treatment guidelines are better managed with the help of newer techniques. Future value propositions for mHealth apps were detailed in Table 2.

CONCLUSION

Managing Tuberculosis is very important, while appropriate therapy compliance is paramount to control tuberculosis. Hurdles to TB treatment compliance are noteworthy and multiple. Mobile health accounts for an arising field with significant promises to locate such barriers, thus enhancing every single individual and community health and health care systems planning. With the newer techniques like mhealth, we can overcome the obstacles of medication adherence to tuberculosis and achieve India’s regulatory targets to eradicate tuberculosis by the year 2025. WHO targets to eradicate tuberculosis by the year 2030 can be made with the help of newer techniques like mhealth techniques. Mobile health applications can be classified into different applications which support diagnostics and clinical choice building, applications that assist behavioural change to increase adherence with traditional treatment pathways, technology-enabled therapeutic applications and applications plotted fundamentally to convey disease-associated acknowledgement. Applications from every class can hold on worth for patients when utilized being a part of a clinical workflow; But, the stage of evidence is presently very light, which is only adequate to assist the usage of applications in a lesser number of specific clinical framework and lot more to explore concerning mHealth techniques in chronic diseases. Moving into the modern generation, mobile phones play a vital role in the health care sector.

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Conflict of Interest

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