Review Article

Mobile Health Technology in the Prevention and Management of Type 2 Diabetes

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Abstract

Essential steps in diabetes prevention and management include translating research into the real world, improving access to health care, empowering the community, collaborative efforts involving physicians, diabetes educators, nurses, and public health scientists, and access to diabetes prevention and management efforts. Mobile phone technology has shown wide acceptance across various ages and socioeconomic groups and offers several opportunities in health care including self-management as well as prevention of Type 2 diabetes mellitus (T2DM). The future seems to lie in mobile health (mHealth) applications that can use embedded technology to showcase advanced uses of a smartphone to help with prevention and management of chronic disorders such as T2DM. This article presents a narrative review of the mHealth technologies used for the prevention and management of T2DM. Majority (48%) of the studies used short message service (SMS) technology as their intervention while some studies (29%) incorporated applications for medication reminders and insulin optimization for T2DM management. Few studies (23%) showed that, along with mHealth technology, health-care professionals' support resulted in added positive outcomes for the patients. This review highlights the fact that an mHealth intervention need not be restricted to SMS alone.

Keywords: Management, mobile health, mobile health technology, prevention, Type 2 diabetes mellitus

Introduction

Globally, Type 2 diabetes mellitus (T2DM) prevalence has increased to about 415 million in 2015,[1] and it is estimated to rise to 642 million by 2040, equivalent to around one in ten adults.[2] According to the International Diabetes Federation, a person with diabetes spends only about 10 h with their physician in a whole year.[3] Although mobile health (mHealth) may not be a substitute for professional health care, it could play a supportive role in diabetes prevention and management by empowering individuals with information related to the primary, secondary, and tertiary prevention so that they might be able to make knowledgeable decisions about their lifestyle and behaviors.[3] Given that T2DM prevention and management is largely dependent on individual behaviors, extending support beyond the clinic may help in self-management. There have been many interventions looking at the effect of face-to-face interventions to support T2DM prevention and management such as the Da Qing study,[4] Finnish Diabetes Prevention study,[5] US Diabetes Prevention Program (DPP),[6] and Indian Diabetes Prevention Program.[7] A less study population are those made recently accessible through the numbers of mobile phone users having increased to over 3 billion (and rapidly rising).[8] Furthermore, mobile phones, which are now referred to as smartphones, bring wireless technology providing the capacity to provide instant access to information and aid in instant communication.[9] This sets the platform for health care to use this ubiquitous advantage in the prevention and management of chronic diseases.

The aim of this narrative review is to present an overview of the mHealth technologies used for prevention and management of T2DM.

We conducted a review of the literature using common online library databases including MEDLINE, PsycINFO, Embase, and many more. The databases were searched between

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February 2015 and October 2016. The search terms were a combination of: "type 2 diabetes mellitus AND mobile phone/cell phone," "type 2 diabetes prevention AND mobile phone/cell phone," "type 2 diabetes control AND mobile phone/cell phone," "type 2 diabetes management AND mobile phone/cell phone," "type 2 diabetes AND mobile health AND mobile phone/cell phone," "Mobile phone* AND type 2 diabetes prevention", "Mobile phone* AND type 2 diabetes mellitus NOT type 1 diabetes," "Cell phone* AND type 2 diabetes mellitus NOT type 1 diabetes," "text messag* AND type 2 diabetes mellitus NOT type 1 diabetes mellitus," "mobile application* AND type 2 diabetes mellitus NOT type 1 diabetes mellitus," "mobile technolog* AND type 2 diabetes mellitus NOT type 1 diabetes mellitus," mobile health/mHealth/m-health AND type 2 diabetes mellitus NOT type 1 diabetes mellitus, and eHealth/e-health/website/web/web-based/website-based/online/internet AND type 2 diabetes mellitus NOT type 1 diabetes mellitus. Inclusion criteria were publications in English, Type 2 diabetes interventions (including only those focused on prevention and/or management) on humans, and specifically, interventions offered using mHealth technologies. Method papers that did not report study outcomes were excluded from the study. Other exclusion criteria included those interventions that used wired technologies, involved face-to-face interventions, focused on multiple diseases, other types of diabetes, or a primary outcome related to those other than prevention or control of T2DM. Of the final 21 studies included, one study was a cluster randomized study, two were quasi-experimental studies (one was pre- and post-test), four were feasibility tests, one was a pre- and post-controlled study, and the rest were randomized control studies. The flowchart of studies reviewed is now added as Figure 1.

Mobile Health Technology

Mobile communication technology is the fastest growing sector of the communications industry with a high geographical coverage with many advances in the mobile technologies.[10,11] The World Health Organization (WHO) considers mHealth as a component of electronic health (eHealth). The definition of eHealth according to the WHO is "the use of information and communication technologies for health" while mHealth is defined as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices."[12] Free *et al.*[11] have defined mobile technologies to include a range of devices such as mobile phones, PDAs and PDA phones, smartphones, enterprise digital assistants, portable media players, handheld media players, handheld video-game consoles, handheld and ultraportable computers,

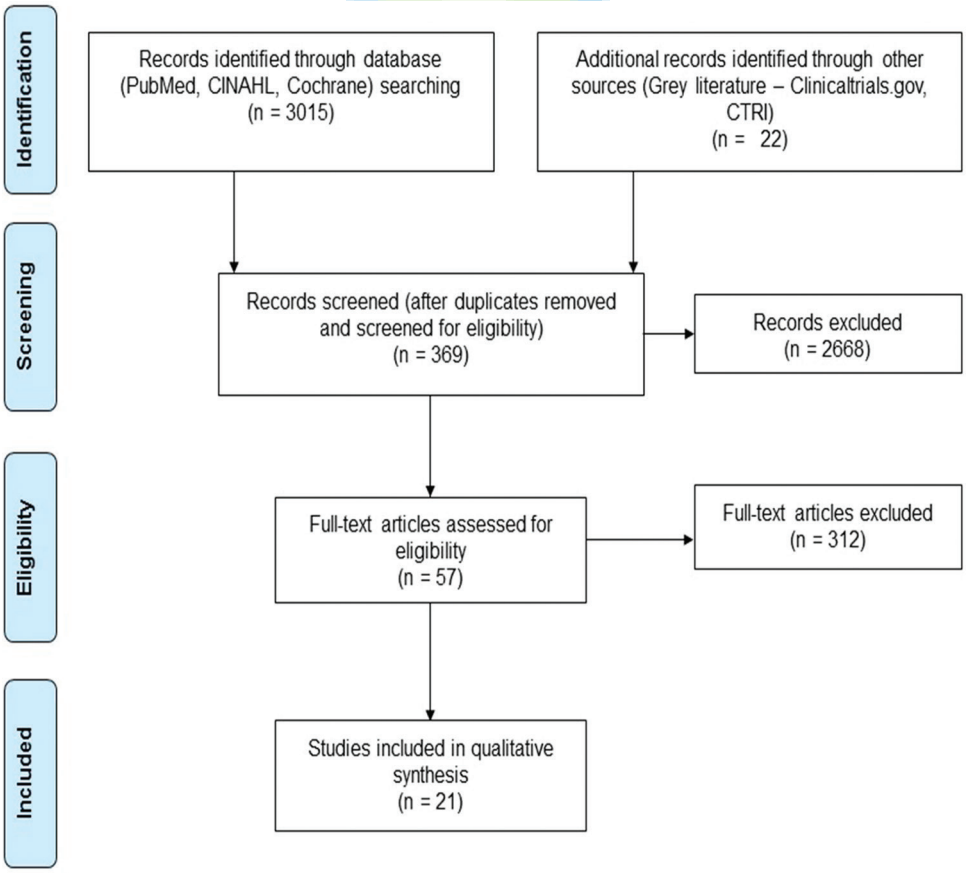

Figure 1: Flowchart of studies included in the review

and smartbooks that include various functions including mobile cellular communications such as short message service (SMS), phone calls, multimedia messaging service, access to the internet, and software applications. This transformative potential of mHealth technology owing to the extraordinary growth of mobile phones, fast growth of mobile networks, and technology[13,14] could render mHealth as a powerful media for providing individual level support beyond traditional/usual care paving the way forward for mHealth opportunities.[12,15,16]

Interventions Using Short Message Service Technology

A majority of the studies published seem to have used SMS technology in T2DM prevention or management. SMS is a telecommunications technology available on all wireless devices to enable quick communication between individuals. A large number of interventions are focused on SMS technology. Most of the interventions that used SMS are focused on T2DM management more than prevention. Table 1

Table 1: Description of studies using short message service technology

Reference	Country/ region	Study design	Sample description	Results
Pfammatter *et al*.[17]	India	A prospective, parallel cohort design	*n*=1925, adults above the age of 18 years who opted to receive text messages as motivation to improve diabetes risk behaviors and increase awareness about the causes and complications of diabetes	The intervention group reported an improvement in diabetes risk behaviors, specifically in fruit, vegetable, and fat consumption
Bin Abbas *et al*.[21]	Saudi Arabia	Nonrandomized experimental trial	*n*=100, adults with T2DM diagnosed for over a year with no complications	The HbA1c decreased from 9.9% to 9.5%, mean knowledge testing showed increase from 17 to 19
Haddad *et al*.[20]	Iraq	Feasibility study	*n*=42, participants were recruited from an outpatient clinic and were in the 1st year following diagnosis (mean-6 months), regardless of microvascular complications and were treated with diet and antidiabetic drugs, own mobile phone and understand/access to assistance in reading SMSs	The mean knowledge increased from 8.6 to 9.9, and the mean HbA1c deceased from 9.3% to 8.6%
Arora *et al*.[24]	United States	Randomized control trial	*n*=128, participants with T2DM with HbA1c ≥8%, speaks and reads English or Spanish, and uses text messages on their mobile phones	The intervention (TExT-MED) group showed decrease of 1.05% in HbA1c when compared to the control group (0.60%). Among secondary outcomes, the TExT-MED group showed increased medication adherence
Wong *et al*.[18]	China	Pilot single blinded randomized control trial	*n*=104, Chinese professional drivers identified with prediabetes within the previous 3 months and if accessible by a mobile phone that could receive Chinese text messages	6% developed T2DM in the intervention group compared to 16% in the control group. NNT therefore was 9.1
Ramachandran *et al*.[19]	India	Prospective, parallel-group, randomized controlled trial	*n*=537, working Indian men aged 35-55 years, ownership/ability to read and understand mobile phone messages in English, a positive family history of T2DM and BMI ≥23 kg/m^2	18% developed T2DM in the intervention group compared to 27% in the controls (*P*=0.015). Significant changes in HDL level and total energy intake in the intervention group were also observed
Goodarzi *et al*.[23]	Iran	Randomized control trial	*n*=81, adults above 30 years of age who are known cases of T2DM, HbA1c above 7 with no complications for more than a year, and owning a mobile phone with ability to handle its SMS feature	Significant changes in HbA1c, LDL cholesterol, BUN, microalbumin, knowledge, practice, and self-efficacy when compared to control group
Hussein *et al*.[22]	Middle East	Feasibility study	*n*=34, newly diagnosed T2DM, age above or equal to 18, HbA1c ≥7.5%, and/or on insulin	Significant difference in HbA1c between the groups resulting in a 1.16% decrease in HbA1c compared to the controls, however, there was no difference in weight
Faridi *et al*.[25]	United States	Randomized control trial	*n*=30, age ≥18, controlled diabetes, BMI >25, HbA1c <8%, no insulin use, and serum creatinine <1.5 mg/dL	Improvement in HbA1c and self-efficacy were reported in comparison to controls
Kim and Kim[26]	Korea	Quasi-experimental design with pre- and follow-up tests	*n*=40, individuals with diabetes according to the ADA criteria, obesity was defined as BMI >23 kg/m^2, participants were required to be able to self-monitor blood glucose, self-inject in case on insulin, and should have owned cell phone	The study reported a mean decrease in HbA1c at all testing points in the intervention group, however, not significantly different from the control group

BMI: Body mass index, ADA: American Diabetes Association, SMSs: Short message services, HbA1c: Glycated hemoglobin, HDL: High-density lipoprotein, LDL: Low-density lipoprotein, BUN: Blood urea nitrogen, T2DM: Type 2 diabetes mellitus, NNT: Numbers needed to treat

gives a detail on the interventions done using SMS technology.

Studies of these technologies applied both theory-based SMSs as well as general diabetes care SMSs, and in each case, they demonstrated an effect on glycemic control. Three studies reported the use of theories in their intervention build. A large text messaging intervention carried out in one million individuals in India tested whether exposure to text messages without any cost-based activity such as in-person visits or counseling could result in behavioral changes and lower diabetes risk by helping participants engage in healthy habits such as increasing their physical activity, avoiding foods high in fat, and increasing fruit and vegetable intake. The text messages were tested by a behavior change task force before being disseminated. This intervention emphasizes the potential for large-scale translational trials in low- and middle-income countries where reaching the majority of the population may be a challenge.[17] Wong *et al.*[18] developed an SMS intervention based on the theory of planned behavior and social cognitive theory. The individuals in the intervention group received the SMS thrice weekly for the first 3 months, once a week in the next 3 months, and once a month for the subsequent 12 months. The study conducted in India by Ramachandran *et al.*[19] used SMS for the intervention and was based on the transtheoretical model (TTM) of behavioral change. The SMS timing and frequency was tailored to the individual's preferences, receiving two to four messages per week. Both the SMS interventions indicated a decrease in diabetes incidence. Wong *et al.*[18] showed that the overall incidence of T2DM decreased in the intervention group (11%) compared to the controls (18%) at 24 months while Ramachandran *et al.*[19] showed that the cumulative incidence of T2DM was lower in the intervention group (18%) compared to the controls (27%). Haddad *et al.*[20] developed SMS based on diabetes education and categorized it into five themes relating to diet, treatment, complication, awareness, blood glucose monitoring, and enhancement of clinic attendance based on T2DM education while Bin Abbas *et al.*[21] developed SMS based on general diabetes care with an aim to induce glycemic control; both interventions resulted in reductions in glycated hemoglobin (HbA1c) and improvement in patient knowledge.

Another alternate intervention was bidirectional, allowing continuous, and individualized support to patients with T2DM through SMSs allowing individuals with T2DM to interact with clinicians and diabetes care educators to improve on their diabetes knowledge and self-management skills. Hussein *et al.*[22] reported that this form of an approach could decrease HbA1c significantly by 1.16%. While the interventions mentioned so far were higher in delivery frequency, Goodarzi *et al.*[23] sent weekly SMSs based on knowledge, attitude, practice, and self-efficacy and showed significant differences between the intervention (0.89%) and control (0.35%) groups in HbA1c. A unidirectional SMS intervention by Arora *et al.*[24] focused on motivating patients to engage in self-care activities and demonstrated a significant improvement in medication adherence although there was no significant decrease in HbA1c.

Interventions Using Mobile Health Technology as Decision Support Systems

mHealth technology may be used as embedded decision support system or clinical decision support system. While systems that support clinical decision-making may help clinicians in understanding patient data, embedded decision support systems can help health-care professionals provide recommendations that can analyze patient feedback. Interventions provided patients with tailored, patient-specific data either in the form of messages[25-27] or letters.[28] Some interventions created algorithms to provide automated recommendations which were built based on theories such as health behavior change theory.[29]

Interventions Using Mobile Application Technology

Mobile application refers to software application designed to run on mobile devices such as smartphones and tablet computers which extend the simple text send and response approach described above. Fukuoka *et al.*[30] developed a 6 weeks' curriculum by modifying the original 16-week DPP curriculum. This was delivered to the intervention group in person and through a mobile phone application. The mobile application was used to reinforce the in-person sessions, and this was done using daily messages, video clips, and quizzes. In this case, positive reinforcement was used to increase the probability of the desired outcomes. Wayne and Ritvo[31] identified one gap in usual care that the approach could overcome was where participants were unable to attend health-care appointments due to familial or work-related responsibilities. In this case, the use of a mHealth application served as a support system. The Few Touch Application, a mobile phone application, was used to help self-manage blood glucose, food habits, physical activity, and personal goal setting along with provision of diabetes information. The trial showed that use of the application along with counseling showed a significant improvement in T2DM self-management. Quinn *et al.*[32] also demonstrated that mobile phone diabetes coaching along with analyzed data given to physicians using evidence-based guidelines had greater effect on glycemic control. While the pace of development has been rapid, we must provide more scope for more mHealth apps to be developed and tested as there remains a lack of evidence basis and evaluation which makes it a challenge for sustainability.[33]

Mobile Health for Insulin Users

Self-management of T2DM pertains to daily activities such as administering insulin, exercising, and resting that go hand in hand with one's treatment to improve one's quality of life. mHealth technology of three steps: adhering, adapting,

and performing routinely. Larsen *et al.*[34] developed an insulin optimization intervention for individuals with poorly controlled diabetes with an aim to promote blood glucose control. The participants were given a mobile phone with preloaded software that enables individuals to enter blood glucose readings and obtain quantity of insulin to use, a glucometer with a Bluetooth cradle to easily transfer data into the phone. These data were reviewed by a diabetes nurse who could contact participants in case of any abnormal value, provide medical nutrition therapy, and refer to the physician to help optimize medical therapy, if need be. The study resulted in a mean HbA1c decrease of 0.69% over 6 months. In a similar study by Turner *et al.*,[35] the authors reported a decrease in HbA1c of 0.91% over 3 months.

The Place of Theory in Interventions

In general, interventions using mHealth technologies usually target or reinforce healthy behavior. Fukuoka *et al.*[30] used a mobile application to reinforce the face-to-face learning. Social cognitive theory and theory of planned behavior are commonly used in eHealth interventions.[18,36] Wong *et al.*[18] developed SMSs based on the theory of planned behavior and social cognitive theory and grouped the SMSs into 4 broad themes including information on diabetes and prediabetes, lifestyle modification, social influence on lifestyle change, and self-efficacy to prevent T2DM in prediabetes patients. This randomized controlled trial showed that the incidence of T2DM was lower in the intervention group (6%) when compared to the control group (16%). Ramachandran *et al.* conducted a randomized controlled trial using SMSs based on the TTM as a foundation for lifestyle modification on working Indian men and tested it against standard lifestyle advice. The SMSs in the study were modeled according to the five stages of behavioral change as in TTM, namely, precontemplation, contemplation, preparation, action, and maintenance, and the participants in both the groups were tested at each stage.[19] Pfammatter *et al.* indicated an improvement in at least two diabetes risk behaviors in a large cohort of high-risk population (20% of intervention group vs. 11% in the control group) using unidirectional SMSs developed by a behavioral change task force.[17] Riley *et al.* urge that theory-driven intervention to improve mHealth interventions alongside strengthening health behavioral theories. Although the use of health behavior theories is rapidly increasing, there is a lack in data that shows evaluation of the theoretical components. As a result, reproducibility of such interventions may be questionable.[36] The use of SMS seemed to be low-cost and less burdensome in terms of delivery. Although it is still unclear as to whether participant-specific messages, theory-based messages or general messages have impact on T2DM prevention or management; as from this review, all three types of messages seem to have an impact.

Barriers in Mobile Health Interventions

Various technological barriers were reported across studies including network issues, individuals changing numbers, and interference from telecommunications providers. In the SMS intervention by Faridi *et al.*[25] which used the NICHE technology providing participants with phone, glucometer, and pedometer, technological barriers reported were that there were too many menus to navigate through, with small buttons, making it difficult to follow when the process altered too often. The pedometers, on the other hand, were reported to be uncomfortable to wear around and with the batteries draining out too often resulting in frequent reprogramming to have affected the ease of use of the intervention at large. In another study by Cho *et al.,*[37] the participants were provided with a "diabetes phone" – a mobile phone with a glucometer inbuilt into the battery pack. When it came to clinical implementation, "diabetes phone" was not a cost-effective approach.[38]

Although mHealth applications may be able to transmit and store large amounts of health-care data, there is a growing concern about the privacy of the data accessibility, confidentiality, and storage.[33] To address this concern, the US Food and Drug Administration under the Food, Drug, and Cosmetic Act ensures that all mHealth apps including devices are regulated, based on their functionality and risk of the data collected, and disseminated before it can be used.[39] A recent review on the feasibility and efficacy of telemedicine for diabetes in India[40] highlights the lack of strict regulatory protocols in delivering interventions for the prevention or management of health conditions through telemedicine. Standardized protocols need to be adapted to all eHealth interventions (thus including mHealth) which can help minimize communication errors between the provider and the user.[40] Many physicians are skeptical about transitioning to mHealth from traditional ways mainly because of the effort it will take to change from an old system to a new one. In addition, although many physicians believed that technology had the ability to improve quality of care, in the long run, they found adaptability a challenge.[41,42]

Another critical aspect of mHealth platforms is the user experience. User experience has a major role in improving their engagement with the app, thereby gaining motivation to use and interpret the content better. Using adept user interfaces with real-time data interpretation and smart algorithms may be useful in developing improved user experience, thereby improving engagement.[43]

Conclusions

Noncommunicable diseases such as diabetes, obesity, cancers, and others are among the main causes of increasing morbidity and mortality worldwide.[1] The field of mHealth although a new field, with its ubiquitous nature and wide adaptability, shows great potential to counter the tremendous burden on health-care costs resulting from noncommunicable diseases.[33,44,45] A successful mHealth platform for T2DM should have a user interface that is visually appeasing, the ability to transfer data real time, involve both the healthcare provider and user, and finally have mechanisms that will motivate the user

to engage constantly with the app. This review shows that mHealth technology with added support from the health-care professionals can result in improved outcomes in patients with T2DM. It also highlights the fact that a mHealth intervention need not be restricted to SMS alone.

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Conflicts of interest

There are no conflicts of interest.

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