Diabetes Management via Mobile Phones: A Systematic Review

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Abstract

Background: *This study sought to understand the most common uses and functions of mobile phones in monitoring and managing diabetes, their potential role in a clinical setting, and the current state of research in this area.* **Methods:** *We identified peer-reviewed articles published between 2000 and 2010. Twenty-one articles were analyzed for this systematic literature review.* **Results:** *The majority of studies examined the use of mobile phones from the patient's perspective. Subjects with type 1 diabetes were enrolled exclusively in over 50% of the studies. Seventy-one percent of the studies used a study-specific application, which had supplemental features in addition to text messaging. The outcomes assessed varied considerably across studies, but some positive trends were noted, such as improved self-efficacy, hemoglobin A1c, and self-management behaviors.* **Conclusions:** *The studies evaluated showed promise in using mobile phones to help people with diabetes manage their condition effectively. However, many of these studies lacked sufficient sample sizes or intervention lengths to determine whether the results might be clinically or statistically significant. Future research should examine other key issues, such as provider perceptions, integration into a healthcare practice, and cost, which would provide important insight into the use of mobile phones for chronic disease management.*

Key words: *home health monitoring, telecommunications, telehealth*

Introduction

Diabetes is a well-documented health problem in the United States and worldwide. The Centers for Disease Control and Prevention reports that about 25.8 million people (8.3%) in the United States have been diagnosed with this disease.[1] Worldwide, approximately 220 million people have diabetes, and estimates suggest this number will grow to 366 million by 2030.[2] Past research has found that patients who use self-monitoring techniques, including monitoring food intake, physical activity, and glucose levels, have better control of their disease.[3,4]

One way that has been proposed to help individuals better manage their diabetes is through use of mobile phones, which are now widely available, offer a variety of communication methods, and are relatively inexpensive. The availability of mobile phones worldwide is growing, and at the end of 2010 the International Telecommunications Union posits that there will be an estimated 5.3 billion mobile cellular subscriptions.[5] Text messaging, also known as short message service (SMS), is a relatively low cost way to send asynchronous messages via mobile phones and is increasing in popularity. An estimated 200,000 text messages are sent every second.[5] In the United States, among teenagers (12–17 years old) who have a mobile phone, over 54% send daily text messages, and almost half send 50 or more text messages per day.[6] Additionally, a recent report from the Pew Research Center[7] states that 7% of mobile phone users have used their phone to search for health or medical information. This trend is higher among younger people, as 29% of 18–29 year olds have performed this type of search. The use and prevalence of mobile applications are also on the rise, as evidenced by the fact that a search for "Diabetes" within the iPhone® (Apple) App store yields 262 results as of March 2011.

Because of the seemingly ubiquitous nature of mobile phones, many researchers and health providers have used mobile phones as a way to educate or help people to manage their health issues.[8–12] Similar to previous research that has examined the use of mobile phones for diabetes,[10] this study sought to examine the types of mobile phone-based interventions implemented among people with diabetes and the potential effect of these interventions on patient outcomes.

Methods

SEARCH STRATEGY

This study began by searching the following electronic databases: Science Citation Index Expanded, Social Sciences Index, Art & Humanities Citation Index, and ProQuest for peer-reviewed articles published between 2000 and May 2010. Search terms included various combinations of the terms "diabetes," "diabetes mellitus," "mobile phone," "cell phone," "cellular phone," "text messaging," "text message," "SMS," and "short message service." References of identified articles were also searched for potential articles for inclusion. Only articles published in peer-reviewed scientific journals in English were eligible for review. The studies reviewed also had to use the mobile phone as the primary device of the intervention.

STUDY SELECTION

We identified 28 articles that met the basic criteria of our search. However, when the articles were further reviewed, seven articles were excluded, primarily because the mobile phone was not the main study intervention technology or the article was a description of a planned intervention that had not yet been implemented. Thus, in total, 21 articles were analyzed for this systematic literature review (*Table 1*). All articles were independently reviewed and coded by the authors, and the following data were extracted: self-care/management activities (i.e., glucose monitoring, eating/diet, physical activity), method of intervention (i.e., application, text messaging only, combination), intervention activity (i.e., diary/log, reminder, informational), outcomes measured (i.e., hemoglobin A1c [HbA1c], body mass index [BMI], self-efficacy, knowledge, satisfaction/usefulness), and method of data transmittal. Additionally, study design and duration, type and glycemic control of diabetes, sample size, study participant (i.e., patient, physician, nurse, informal caregiver) recruitment process, phone ownership, location, costs, and reported technical issues were examined (*Table 2*). Both coders had previous coding experience and were well versed in the area of mobile health. During the process of establishing reliability, the coding scheme was refined and explicated as necessary. Once reliability was established (Krippendorff's alpha $\geq$ 0.8 for each coded item), any discrepancies between the two reviewers were subject to multiple reviews and then settled by consensus.

Results

STUDY DESIGNS AND SUBJECTS

The majority (95%) of studies examined the use of mobile phones from the patient perspective, while 19% took into account the healthcare providers (physicians [14%], nurses [5%]), and two studies (9.5%) included informal caregivers, such as parents of the patient. Sample sizes ranged from 6 to 100 subjects, with a mean of 38 subjects and a median number of 30. Subjects with type 1 diabetes were used exclusively in 57% of the studies, 19% had patients with type 2 diabetes only, 10% of the studies used patients with both types, and 14% of the studies did not report this information. Level of glycemic control, as measured by HbA1c, was reported in 57% of studies.

Almost half of the studies had some type of participant randomization (47.6%). Two studies utilized a crossover design in their intervention. The length of the interventions varied from 2 weeks to 1 year. The average length of intervention was 22.5 weeks, excluding two studies that did not report intervention length. Fourteen of the 21 studies described participant inclusion and exclusion criteria. Having a comorbidity was the most commonly stated exclusionary factor (23.8%), whereas the most commonly reported inclusion criterion involved participant age (62%). Treatment with insulin was required by one-third of studies. Seventy-one percent of studies explicitly stated the location of the intervention; these studies took place in the United Kingdom ($n = 5$), the United States ($n = 4$), Scandinavia ($n = 3$), and continental Europe ($n = 2$).

MOBILE PHONE TECHNOLOGIES

Over half of studies (57%) provided a mobile phone to the subjects, whereas 14% had subjects use their own phone, and 29% did not report this information. One-third of studies stated that the study paid for the mobile phone service, and two-thirds of studies did not report who paid for the service. Additionally, four studies discussed overall cost data. Technical issues, such as lost messages or limitations of coverage area, were reported in 67% of studies.

Seventy-one percent of studies used a study-specific application, which is a program that was developed for the study and has more functionalities or features than simple text messaging. The type of function (i.e., diary/log, reminders, information/education) used in the intervention varied, and many studies included multiple functions. Messages that reminded the participant to do an activity were used in 52% of the studies. Six studies (39%) used the messages as an opportunity to educate the participants with tips and information about diabetes. Eighty-one percent of studies reported using a diary function to record data such as blood glucose readings, carbohydrate or calorie consumption, or physical activity. The most common transmission methods of blood glucose values were Bluetooth® (Bluetooth SIG, Inc.) (62.5%), a physical wire to the phone (12.5%), or infrared signaling (12.5%) between the phone and the glucometer. Studies that did not develop or use a study-specific application used text messaging only. In these instances, subjects had to manually enter their information into the mobile phone and send it.

OUTCOMES REPORTED

The studies reviewed used many different outcome measures, making it difficult to do a rigorous analysis of the clinical findings. Outcomes related to self-care and management activities were reported by 43% of studies. These activities included glucose monitoring (67%), eating (44%), and exercise (44%). Sixty-two percent of studies reported HbA1c as an outcome measure, of which 85% reported improvements. However, statistically significant changes in HbA1c were reported in only three of the studies. BMI was an outcome in 24% of studies, and no significant changes were found. Self-efficacy was reported as an outcome by 24% of studies, and all found nonsignificant improvements. Knowledge about diabetes and diabetes management was reported as an outcome in 14.3% of studies, with improvements reported in two studies. Information about the costs associated with this type of intervention was reported in four studies. Of the 48% of studies that reported satisfaction as an outcome measure, 90% of them reported that the subjects were satisfied with this type of intervention.

Discussion

This review highlights the work that has been done in using mobile phones to help people with diabetes manage their disease and improve health and behavior outcomes. When one considers the ubiquity of mobile phones in modern life and their increasing use for health applications, the amount of research conducted about using them for diabetes management seems comparatively small. The studies evaluated demonstrate many positive trends, but few significant findings were reported. The small number of significant findings could be due to the small sample sizes; the average number of subjects in the studies reviewed here was 38, and just under half were randomized to a condition. Also worth noting is the fact that many of the studies did not report power calculations. Thus, overall, the generalizability of the data as they relate to other populations is

Table 1. Summary of Studies Analyzed

AUTHOR, YEAR	SUBJECT TYPE	NUMBER OF SUBJECTS	DURATION OF STUDY	STUDY TYPE	STUDY LOCATION	PHONE PROVIDED	TYPE OF TECHNOLOGY AND FUNCTION(S) USED	TYPE OF DIABETES	SUMMARY OF RESULTS
Carroll et al.,[20] 2007	Patients	10	12 weeks	Pilot study, to test user satisfaction	Indiana, USA	Yes	Integrated glucometer and phone, application, diary	Type 1	Technology use: High agreement regarding subjects used this device the same or more than normal glucometer, used diabetes phone as communication tool. Satisfaction/usefulness: High agreement regarding subjects liked the mobile technology, having the glucometer contained within their phone. Moderate agreement regarding ease of use and usefulness. Neutral regarding the usefulness of Web site, ease of contacting their physician. Social outcomes: High agreement that it made it easier to get around at school. Neutral regarding impact on relationship with physician, frequency of communication with physician. Disagreement regarding the impact on relationship with parents.
Istepanian et al.,[21] 2009	Patients	72 (intervention), 65 (control)	36 weeks	RCT, testing HbA1c differences between telemonitoring and regular monitoring	England, UK	Yes	Application, Bluetooth, diary	Type 2, type 1	Clinical outcomes: There were no differences between the telemonitoring group and the control arm in HbA1c ($p=0.17$). Subjects who completed the entire telemonitoring intervention (numbers not indicated) had a nonsignificant lower HbA1c ($p=0.06$).
Quinn et al.,[18] 2008	Patients, physicians	30 (15 intervention/ 15 control)	12 weeks	Randomized, assess the usability and impact on patient HbA1c outcomes and HCP prescribing	Maryland, USA	Yes	Application, Bluetooth, reminder, diary	Type 2	Clinical outcomes: Statistically significant improvements in HbA1c values. Subjects in intervention were more likely to have their physician intensify diabetes medications. Providers and patients were satisfied with the system.
Katz and Nordwall,[17] 2008	Patient, physicians	30 (15 intervention/ 15 control)	12 weeks	Pilot-controlled clinical trial evaluating efficacy and feasibility	Not reported	Not reported	Application, SMS, Bluetooth, diary	Type 2	Clinical outcomes: Improved levels of HbA1c. Self-care: Improvement in self-efficacy, improved diabetes self-care activities.
Benhamou et al.,[22] 2007	Patients	30	52 weeks	Randomized, crossover measuring HbA1c, safety, quality of life, adherence to testing	France	Yes	Application, SMS, infrared, diary	Type 1	Clinical outcomes: Nonsignificant improvement in HbA1c. Quality of life was improved. No difference in number of hypoglycemic episodes between groups. Self-care: Improved adherence to testing (only in a portion of the study period).
Curran et al.,[23] 2010	Patients	6	2 weeks	Test user interface and transfer of information, testing the neural network approach	Ireland, UK	Not reported	Application, diary	Not reported	Satisfaction/usefulness: They found their approach has value. Found implications for future research regarding insulin pumps. Researchers received positive feedback from subjects.
Farmer et al.,[24] 2005	Patients	94 (46 used the system with full functionality)	Not reported	Random, sought to describe the way the system was implemented and used	Not reported	Not reported	Application, SMS, wired phone to glucometer, reminder, diary	Type 1	Technology use: Over 57,000 messages were collected. Clinical outcomes: Increased numbers of patients achieved HbA1c of $<8\%$ (not significant). Self-care: Phone-based feedback prompted attention to glucose levels to allow users to adjust insulin. Regular blood glucose monitoring was higher among intervention group (not significant).

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Table 1. Summary of Studies Analyzed *continued*

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Faridi et al.,[16] 2008	Patients	30 (15 intervention/ 15 control)	12 weeks	Random, test feasibility, clinical outcomes (HbA1c, BMI, blood pressure, physical activity, self-care, and self-efficacy)	Connecticut, USA	Not reported	SMS, wireless biometric devices to transmit clinical data that transmits tailored feedback to patient via SMS, reminder	Type 2	Technology use: Two subjects in the intervention group were completely adherent; four subjects used the intervention for 1–2 months; four subjects used it for 1 week; five did not transmit information. Satisfaction/usefulness: Technical problems were reported with equipment. Usability issues: Too many menus, small buttons, commands changed frequently. Most preferred usual diabetic self-management.
Ferrer-Roca et al.,[25] 2004	Patients	23	32 weeks	User satisfaction, system use, and cost data were analyzed.	Not reported	Subjects used own phone	SMS, diary	Not reported	Technology use: Average of 33 SMS messages per month from 23 subjects. Reduction of messages during the holidays. Satisfaction/usefulness: Overall user satisfaction was good ($n=6$ responses). Cost: The cost analysis was based on subjects using their own phone and SIM card and estimate €3/month for the user and the cost of the manager to be €3.75/month per patient.
Franklin et al.,[26] 2008	Patients	64	52 weeks	Utility of intervention and examine user interaction	Not reported	Yes	SMS, reminder, entertainment, information/ educational message	Type 1	Technology use: 1,180 messages were submitted during the study period. Five subjects used the system the majority of the time (52% of all messages). Female subjects sent more messages not regarding diabetes. Unprompted submission of blood glucose was most common message type. Responses to requests for personal experience and tips accounted for 40% of incoming messages as well as asking questions and ordering supplies. Subjects did not request that an outside (of the study) person receive texts regarding the subjects' status.
Gammon et al.,[27] 2005	Patients and informal caregivers	30 (15 children/ 15 parents)	16 weeks	Self-selected child (with diabetes)–parent dyads were used, both user groups were asked about use and satisfaction, and some parents were interviewed regarding experiences, advantages and disadvantages.	Norway	Yes (for children/ parents used own phones)	Application, SMS, Bluetooth, diary	Type 1	Technology use: System was used 3–4 times/day. Satisfaction/usefulness: When the children were away from home, both groups thought the automatic transfer of blood glucose levels was good. The parents had higher levels of satisfaction than the children. All parents felt the system provided reassurance. Parents liked knowing if their child has measured his or her blood glucose. Information provided was good for recently diagnosed children. Individuals thought the system should be more automated. Self-care: Living with diabetes was easier with the phone. Social outcomes: Mixed interview findings regarding nagging, independence of self-management, and surveillance of self-management activities.

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Table 1. Summary of Studies Analyzed *continued*

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Vähätalo et al.,[14] 2004	Patients	203 (101 control/102 intervention)	52 weeks	Use of the application, weight, insulin dose, and HbA1c	Finland	Yes	Application, SMS, diary, information	Type 1	Technology use: Average number of blood glucose readings transferred was 9.1/week. Subjects who were identified as working in a technical field sent more messages. Clinical outcomes: Insulin dose of the intervention group increased significantly. Slight overall increase in HbA1c for both groups (minor change in methodology of HbA1c measurement occurred during the study).
Wangberg et al.,[28] 2006	Parents of children with diabetes	11	11 weeks	Randomized, test the feasibility and acceptability of using SMS to provide diabetes information	Norway	Not reported	SMS, information/ educational messages	Type 1	Satisfaction/usefulness: Generally positive feedback regarding the system. Findings indicate the system was good at providing new and updated information about diabetes and information about the parents' role in managing a child's diabetes to child's self-management.
Hanauer et al.,[29] 2009	Patients	40 (22 in text message group/18 in e-mail group)	12 weeks	Randomized, usability, preference, blood glucose levels	Not reported	Subjects used their own	Application, SMS, reminder, diary	Not reported	Technology use: 18 subjects used the text messaging system; 11 of the e-mail subjects used the system. Females were more likely to use the system. Cell phone group requested more reminders, responded faster to reminders, and submitted significantly more blood glucose test results. Between-group difference decreased as time went on. Satisfaction/usefulness: Half of all subjects reported they would prefer the cell phone; 17% preferred the e-mail; 10% wanted both; two subjects did not prefer either. Clinical outcomes: No difference in glycemic control between groups was found.
Kollmann et al.,[30] 2007	Patients	10	12 weeks	Usage, satisfaction, HbA1c, blood glucose level	Not reported	Yes	Application, SMS, reminder, diary	Type 1	Technology use: 3,850 log-ins were registered over the entire program; 13,003 datasets were transmitted; 85% adherence rate of sending at least three blood glucose values daily. An average log-on and data transfer took approximately 3 min. Satisfaction/usefulness: Application was easy to learn and use. Clinical outcomes: Significant decrease in HbA1c; decrease in average blood glucose level.
Rami et al.,[31] 2006	Patients	36	24 weeks	Randomized, crossover, feasibility and glycemic control	Not reported	Yes	Application, SMS, reminder, diary	Type 1	Technology use: Nine patients sent only < 50% of the 4 daily messages. Clinical outcomes: Group using phone application demonstrated improved glycemic control. Satisfaction/usefulness: Some service area coverage problems were reported by 26 subjects. Patients reported overall satisfaction with the application. Patients did not like the additional workload or the service area problems.

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Table 1. Summary of Studies Analyzed *continued*

AUTHOR, YEAR	SUBJECT TYPE	NUMBER OF SUBJECTS	DURATION OF STUDY	STUDY TYPE	STUDY LOCATION	PHONE PROVIDED	TYPE OF TECHNOLOGY AND FUNCTION(S) USED	TYPE OF DIABETES	SUMMARY OF RESULTS
Rossi et al.,[32] 2009	Patients	50 (DID1) 41 (DID2)	12 weeks	2 pilot studies (DID1 and DID2), feasibility and acceptability, glycemic outcomes	Italy	Not reported	Application, SMS, reminder, diary, information/ education	Type 1	DID1: Technology use: Patients sent average of 10.4 messages per day. Satisfaction/usefulness: Baseline perceptions of the system were good. Patients were interested in trying it and thought it could be helpful. Post-study survey concluded the system led to good satisfaction and was useful, easy to use, and easy to learn. CHO counting tool was ranked the most important function, followed by insulin bolus calculator, food diary, physical activity diary, and food exchange. Communication with provider was ranked as being effective. Technical issues included the speed. Clinical outcomes: No significant differences were shown in HbA1c, blood pressure, BMI, DTSQ-WHO, and SF-36. Self-care: Subjects reported better eating behaviors and reported higher knowledge of diabetes. DID2: Clinical outcomes: Fasting blood glucose and postprandial blood glucose decreased significantly. HbA1c decreased (not significant). Short-acting insulin use decreased. Long-acting insulin use increased.
Tasker et al.,[33] 2007	Patients	37 (19 mobile phone/18 computer apps)	4 weeks	Randomized, ascertain the rate of hypoglycemia, technology preference	United Kingdom	Subjects used their own	SMS, reminders, diary	Type 1	Technology use: 58 responses; 132 hypoglycemic reports over 705 recorded days. Response rate of the mobile phone group was 95%, paper diary 65%, and computer application 89%. Satisfaction/usefulness: High preference for using the mobile phone. Clinical outcomes: 5.2 hypoglycemia episodes/month; all were mild.
Turner et al.,[19] 2009	Patients, HCPs	23 (patient subjects)	12 weeks	Utilization and perceptions	United Kingdom	Yes	Application, Bluetooth, reminder, diary	Type 2	Technology use: 160 blood glucose readings were transmitted per patient. Satisfaction/usefulness: Providers reported they liked the ability to access up-to date information, potential to support patient self-management, and enhancing patient self-management. Technical problems were also reported and addressed during the study. Clinical outcomes: Decrease in HbA1c (not significant). Self-care: Patients reported feeling more in control of their diabetes, increased confidence in self-managing their diabetes.

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Table 1. Summary of Studies Analyzed *continued*

AUTHOR, YEAR	SUBJECT TYPE	NUMBER OF SUBJECTS	DURATION OF STUDY	STUDY TYPE	STUDY LOCATION	PHONE PROVIDED	TYPE OF TECHNOLOGY AND FUNCTION(S) USED	TYPE OF DIABETES	SUMMARY OF RESULTS
Arsand et al.,[34] 2008	Patients	9	Not reported	User feedback and user testing	Washington, USA	Yes	Application, diary, information education	Type 1 and type 2	Satisfaction/usefulness: Subjects reported that recording eating habits was motivating; however, there was a lot of effort involved in doing that manually. Thought the developed tool could be useful. Photo food blog would not be helpful but could help with unfamiliar foods or when talking to an HCP. Preloaded food list with nutritional values was valuable. Touch screen application was thought to be easy to use. The ability to personalize the application was viewed as being important.
Franklin et al.,[13] 2006	Patients	91	52 weeks	Randomized, HbA1c, self-efficacy, diabetes knowledge, diabetes social support	Scotland, UK	Yes	SMS, reminder, information, education	Type 1	Application was used in conjunction with intensive therapy and compared against those not using the application. Technology use: Increase in hotline contacts of those using the insulin pump with the application compared with the intensive therapy and the application (significant). Satisfaction/usefulness: 97% liked the number of messages received. Social outcomes: Improved perceptions of the support they receive. Clinical outcomes: Improvement in HbA1c was shown in the group using the application + intensive therapy. Health service utilization increased stepwise across the groups over the year but remained within protocol. Self-care: Significantly higher scores on the self-efficacy measure (significant). Improved self-adherence scores. No impact on diabetes knowledge scores. 81% thought that the application helped their self-management.

AMI, acute myocardial infarction; BMI, body mass index; CHO, carbohydrate; DTSQ-WHO, Diabetes Treatment Satisfaction Questionnaire–World Health Organization; HbA1c, hemoglobin A1c; HCP, healthcare provider; RCT, randomized controlled trial; SF-36, 36-item Short Form; SMS, short message service.

limited. To move the field forward this issue should be addressed in all future studies. A limitation of this review, however, is that the assessment of outcomes reported was done at a more general level so as to allow for comparison across studies. HbA1c was commonly monitored, but other condition-specific factors assessed by the studies were not completely addressed in this review. It may be the case that the outcomes were more promising for other parameters not discussed here.

Short intervention periods also may have impacted the reported outcomes. For example, the two studies[13,14] that had a study period of at least a year were able to demonstrate a significant effect of the intervention on key outcomes. Additionally, because of the relatively short time frames of most studies, we are unable to determine the long-term impacts of mobile phone diabetes interventions, including retention, adherence, sustainability, and integration into the healthcare system. As diabetes is a condition that requires lifelong management and monitoring, longer intervention lengths may provide better insights.

It is interesting that reports of provider interactions with the patients using the mobile phones were limited in these studies. It is not clear how additional data regarding a patient's diabetes were presented to either the patient's physician or nurse and how medical professionals then integrated this information into their practice. Patients' perceptions of usefulness were reported in just under half (48%) of the studies, with most (90%) reporting that the patients perceived the application positively. However, past research has demonstrated that gatekeepers to the introduction of new technologies are often the healthcare providers.[15] Therefore, it is important to understand providers' perceptions of the challenges and barriers to integrating new technologies that might help improve patient

Table 2. Coding Definitions and Frequencies

DOMAIN	ITEMS CODED	FREQUENCY	*N*
Self-care management			
The care taken by individuals toward their own health and well-being, the actions they take to lead a healthy lifestyle	Eating	19.0%	4
	Exercise	19.0%	4
	Glucose	28.6%	6
Use of application			
How the main intervention was provided to the participants	Application	71.4%	15
Method of data transmittal			
If an application was used, how data was transferred to the phone	Bluetooth	23.8%	5
	Wired	4.8%	1
	Infrared	4.8%	1
	Both	4.8%	1
Not used	Hand-entered	38.1%	8
Intervention activity			
The type of activity that the intervention provided through use of the mobile phone	Reminder	52.4%	11
	Diary	81.0%	17
	Entertainment	4.8%	1
	Information	28.6%	1
Study design			
Were patients randomized to a study condition?	Randomized	47.6%	10
Study duration			
How long did the study last?	Reported	90.5%	19
	In weeks, average	22.5	
Type of diabetes			
Was the intervention developed for a specific type of diabetes?	Type 1	57.1%	12
	Type 2	19.0%	4
	Both	9.5%	2
	Not reported	14.3%	3
Outcomes	BMI reported	23.8%	5
What outcomes did the study examine? If they examined the outcome, what there a change?	Improvement	80.0%	4
	No change	19.0%	1
	Knowledge reported	14.3%	3
	Improvement	66.7%	2
	No change	33.3%	1
	Satisfaction reported	47.6%	10
	Satisfactory/useful	90.0%	9
	Mixed	10.0%	1
	Self-efficacy reported	23.8%	5
	Improvement	100.0%	5
	No change	0.0%	
	HbA1c reported	61.9%	13
	Improvement	84.6%	11
	No change	7.7%	1
	Deterioration	7.7%	1
Sample size			
Was the sample size reported? What was the sample size?	Reported	100.0%	21
	Average	38	
Recruitment process	Inclusion criteria		
Did the study report specific inclusion and exclusion criteria? What were they?	Age	61.9%	13
	Severity of diabetes	28.6%	6
	Length of diagnoses	23.8%	5
	Insulin treatment	33.3%	7
	Access to Internet	14.3%	1
	Ability to use phone	19.0%	4
	Exclusion criteria		
	Comorbidities	23.8%	5
	Pregnancy	14.3%	3
	Mental illness	9.5%	2
	Not willing to monitor diabetes	4.8%	1
	Lived outside of coverage area	4.8%	1
Phone ownership			
Who provided the phone?	Study provided phone	57.1%	12
	Subjects use own phone	14.3%	3
	Not reported	28.6%	6
Study location			
Was the location of the study explicitly stated?	Reported	71.4%	15

continued →

Table 2. Coding Definitions and Frequencies *continued*

DOMAIN	ITEMS CODED	FREQUENCY	*N*
Technical issues			
Were technical issues reported?	Reported	66.7%	14
Study participant			
What group were the participants in the intervention?	Diabetes patient	95.2%	20
	Physician	14.3%	3
	Nurses	4.8%	1
	Informal caregiver	9.5%	2
Cost			
Were any cost data provided?	Cost reported	19.0%	4

outcomes. There may be some hesitation by a healthcare provider or facility in adopting this type of technology, as questions of reimbursement, privacy, and liability may be issues. However, these issues may be addressed by the Food and Drug Administration, which is taking steps to formally approve these types of applications for use in healthcare.

Many healthcare providers and organizations are searching for cost-effective ways of providing high-quality healthcare to patients, and using mobile phones may prove to be one effective strategy. However, cost issues were only mentioned in four of the studies,[25,30–32] and none mentioned reimbursement issues. Cost analysis greatly depends on the equipment used and the timing associated with the intervention, but it will never be truly accurate without measuring the costs when implemented in the "real-world." Another real-world issue regards the provision of the mobile phones to the patients. Many of these studies provided the mobile phones to the patients, so it is unclear if they had their own phone and if the studies' technologies would have worked on them. Moreover, it is unknown if participants felt burdened when having to carry a second, unfamiliar phone, which could also lead to different patterns of usage than if they had used their own device. These issues are important for future studies to address if there are widespread implementation plans.

Overall, subjects' use and engagement in the mobile phone technologies utilized in the studies remain unclear. Some studies reported the number of text messages received and sent as an outcome measure, but it is impossible to gauge the actual level of patient engagement by this metric alone. Some studies only had a fraction of the participants respond to additional surveys that measured such outcomes. Additionally, in the studies that assessed the quantity and frequency of the messages, most report that a few highly active users sent the majority of the messages. Further inquiry is therefore needed to examine the characteristics of these highly active individuals and to work toward determining methods of encouraging other users to become more active. More engaged patients might demonstrate higher self-efficacy in managing their illnesses on a daily basis through use of mobile phones. In the studies reviewed, only a quarter (24%) measured self-efficacy,[13,16–19] with all reporting improvements. These improvements may lead to behavior change and better outcomes over time, but this is unlikely if the subjects do not continue using the technology or are not engaged in the activity.

Future research on the use of mobile phones for improving access and quality of healthcare is seemingly endless, as many mobile applications for health are being developed, and mobile phones continue to become more prevalent. However, many of these potential applications may be outside of the purview of an individual's healthcare team or insurance company; thus access to or awareness of quality or formally approved technologies could be limited. Future studies should examine healthcare providers' acceptance and intention to work mobile phone applications into their practices as well as the impact that these applications might have on patient–provider interaction. Furthermore, research could explore if there is a difference in outcomes between an individual independently deciding to use an application versus having an application recommended by his or her healthcare provider. It is also important to determine the characteristics of patients who would actually use the mobile phones and consequently benefit the most from their use in order to define appropriate referral strategies. Again, future study designs and implementation will need to address the long-term sustainability and outcomes for these types of applications. These types of research inquiries will help to inform the efficient and effective use of mobile phones in managing chronic diseases.

This systematic review has examined studies that used mobile phones to help people manage their diabetes. However, many of the studies evaluated did not use rigorous study designs, and few statistically significant results in patient outcomes were found. Nevertheless, there is promise in that many of the outcomes had positive trends, such as for HbA1c levels, self-efficacy, and diabetes knowledge. Altogether, the studies analyzed suggest that, despite the promise of using mobile phones in this area, much more rigorous research needs to be completed if these technologies are to be proven useful in the management of diabetes.

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