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REVIEW

Analyzing the Effectiveness of mHealth to Manage Diabetes Mellitus Among Adults Over 50: A Systematic Literature Review

Clemens Scott Kruse, Michael Mileski, Katharine Heinemann, Hung Huynh, Abigail Leafblad, Emmanuel Moreno

School of Health Administration, Texas State University, San Marcos, TX, USA

Correspondence: Michael Mileski, Texas State University, School of Health Administration, 601 University Drive, Encino Hall—250, San Marcos, TX, 78666, USA, Tel +1 512 245 3556, Email mileski@txstate.edu

Purpose: A total of 537 million suffered from diabetes mellitus in 2021, and the aging of the population will not abate this number in the future. Diabetes predisposes people to ailments and doubles the risk of COVID-19 mortality. mHealth has shown promise to help manage diabetes. The aim of this review is to objectively analyze research from the last 2.5 years to assess effectiveness where mHealth has been used as an intervention to help manage diabetes in older patients. We also analyzed patient satisfaction, quality, and barriers to adoption of mHealth to manage diabetes.

Patients and Methods: No human subjects were involved in this review. We queried four research databases for mHealth to manage diabetes in older adults. We conducted the review based on the Kruse Protocol for writing as systematic review and we reported our findings in accordance with PRISMA (2020).

Results: Thirty research articles from 11 countries were analyzed. Five interventions of mHealth were identified. Of these mHealth Short Message service (SMS) helped change behavior and encouraged self-care. mHealth SMS coupled with telemedicine for coaching showed positive effects on weight loss, BMI, diet, exercise, HbA1C, disease awareness, blood pressure, cholesterol, medication adherence, and foot care.

Conclusion: mHealth SMS coupled with telemedicine for coaching shows the greatest promise for educating, changing behavior, and realizing positive outcomes across a broad spectrum of health factors. The largest drawback is the cost of acquiring equipment and training users.

Keywords: mHealth, telemedicine, eHealth, telehealth, diabetes mellitus

Plain Language Summary

This systematic review analyzes studies published over the last 2.5 years in academic, peer-reviewed literature to identify mHealth-related interventions to manage Type 2 Diabetes Mellitus. Through data extraction on 30 articles from 11 countries, we identified five mHealth-related interventions. These interventions were found to improve symptoms of Type 2 Diabetes Mellitus, and many interventions show improvement over treatment as usual. Employing technologically-inclined interventions can help meet a preference of patients while still feeling confident about their efficacy. This study has implications for administrators, clinicians, and policy makers.

Introduction

Rationale

Telemedicine is defined as healing at a distance through the use of information and communication technologies.[1] Telemedicine encompasses a wide range of clinical interventions including mHealth and eHealth. The distinction between the latter and former is that the latter involves a computer as the interface while the former involves mobile technology such as a cellular phone or tablet. mHealth and eHealth are forms of telehealth. mHealth uses mobile

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technology to heal at a distance and eHealth uses computer based apps to do the same. These are closely related because most computer applications can be accessed through mobile devices. Mobile devices are convenient, and they are hosting medical-related applications to help patients manage many medical conditions.

It is important to note in studying alternative modalities of care that improvements that are not statistically different from treatment as usual is usually still a significant event to report. Some patients prefer technologically inclined interventions. When an mHealth intervention shows improvement that is close to treatment as usual, it means the provider can assign this intervention to the patient because it fulfils a preference and its efficacy is sound. The advantages inherent to technological interventions such as mHealth is that they allow healing at a distance. They help avoid miles driven and time expended to travel to a medical appointment. They prevent exposure to the medical environment.

Diabetes mellitus "is a heterogeneous group of disorders characterized by hyperglycemia due to an absolute or relative deficit in insulin production or action."[2] This condition is associated with end organ damage, dysfunction, and failure of the retina, kidney, nervous system, heart, and blood vessels. The prevalence of this group of disorders is estimated by the International Diabetes Federation of 537 million in 2021 and predicted to rise to 643 million by 2030.[3] About 90% of those with diabetes have Type 2 diabetes, which is lifestyle-related. This distinction is important because treatments for type 2 do not always work with type 1. Diabetes affects older people more than any other age group ranging from 22–33% of the population.[4] With the aging of the population, diabetes in this age group should have priority because the prevalence will increase as the number of people entering this age bracket increases, thus causing a greater burden to the healthcare system. Diabetes doubles the risk of COVID-19 mortality to older adults.[5]

Type I diabetes is characterized by the destruction of the beta cells of the pancreas, leading to insulin deficiency in the patient.[6] Treatment for type I diabetes includes insulin replacement therapy which meets specific glycemic targets.[6] Type II diabetes is characterized by hyperglycemia, insulin resistance, and impaired insulin secretion.[7] Treatment for type II diabetes includes educational measures, continuous evaluation for vascular complications, minimization of long-term risk factors, lifestyle changes, and attempts to achieve normoglycemia, often using insulin therapy.[8] Resulting from the COVID-19 pandemic, those who suffered from the infection can suffer from type I or type II diabetes and are often seen with severe metabolic manifestations of diabetes which include diabetic ketoacidosis, hyperosmolar hyperglycemic states, and severe insulin resistance.[8,9]

Telehealth has been used as an intervention to help monitor and manage diabetes for decades. It is used for telemonitoring, glucose recording, and communication with providers.[10] The telehealth intervention is associated with convenience, access, and time savings for patients.[11] However, disadvantaged communities are often challenged with limited technological literacy, and telehealth in general is used less by people older than 65.[12] A marked increase in the use of telehealth is evidenced post pandemic, and telehealth is expected to continue to be a frequently utilized treatment modality.[13,14] Management of chronic conditions such as diabetes is increasingly being conducted via telehealth.[14–16] A descriptive systematic review was published in 2017 to explore the enablers and barriers faced by adults with diabetes using two-way information technologies to support diabetes self-management.[17] A team of reviewers analyzed 48 articles and identified enablers (access to reliable technology, highly automated data entry, graphical display of data with immediate feedback, and supportive healthcare professionals and family members) and barriers (poorly designed interfaces and systems that lacked functionalities valued by patients).

A systematic review was published in 2021 that explored the effectiveness of technology-based psychosocial interventions on diabetes distress and health-relevant outcomes.[18] This group of reviewers analyzed 20 randomized control trials to conclude that technology-based psychosocial interventions improved diabetes distress, self-efficacy and HbA1c levels with significant and small effect sizes.

Objectives

The purpose of this review is to analyze the effectiveness of mHealth to manage Type 2 diabetes mellitus self-care among adults greater than 50 years old from literature published over the last 2.5 years in peer-reviewed academic journals.

Material and Methods

Eligibility Criteria

The eligibility criteria for this review is older adults (over the age of 50), research articles published in the last 2.5 years in peer-reviewed, academic journals, using mixed method, quantitative, and qualitative, methods to analyze the relationship between mHealth as an intervention to manage the self-care of diabetes mellitus. Two and a half years was chosen due to the plethora of articles available on this topic, and to focus on research efforts since the beginning of the pandemic. In addition, this time frame produces articles incident to COVID-19, a period when telehealth tools were used ubiquitously in medicine due to the inability to meet face-to-face. In order to avoid confounding results, other systematic reviews were not included in the analysis because systematic reviews already reported on results from studies that may also be counted in our analysis. Articles should report results of studies. Grey literature was only considered if the articles reported results.

Information Sources

Four research databases were queried: PubMed (MEDLINE), CINAHL Ultimate, Web of Science, and Science Direct. They were searched between July 1st and July 20th 2022.

Search Strategy

We created a Boolean search string to combine key terms listed in the Medical Subject Headings (MeSH) of the US Library of Medicine. We used the same search strategy in all databases. The search string was (mhealth OR ehealth OR telemedicine OR smartphone) AND (diabetes OR "diabetes control") AND ('older adult' OR elderly). We used similar filter strategies, because not all databases have the same tools. MEDLINE was excluded from all databases except PubMed to eliminate duplicates.

Selection Process

In accordance with the Kruse Protocol, we searched key terms in all databases, filtered results, and screened abstracts for applicability.[19] At least two reviewers screen each abstract and analyzed each study. Three consensus meetings were held to determine which articles would be analyzed, which data-extraction items were significant measurements of effectiveness, and what observations should become themes. Results were reported in accordance with the PRISMA 2020 standard.[20]

Data Collection Process

We used a standardized Excel spreadsheet to extract data, and we collected additional data at each step of the process. This spreadsheet was standardized in the Kruse Protocol and has developed over a decade of use to collect data useful for clinicians, administrators, and policy makers.[19] We used a series of three consensus meetings to screen abstracts, identify articles for analysis, and identify themes through narrative analysis.[21]

Data Items

In accordance with the Kruse Protocol, we collected the following fields of data at each step: Participants, experimental intervention (mHealth), results compared with a control, medical outcomes commensurate with the intervention, study design, sample size, bias identified in the study, effect size, country of origin, statistics used, patient satisfaction, quality associated with the intervention (effectiveness), barriers to adoption, strength of evidence and quality of evidence.

Study Risk of Bias Assessment

We observed bias and assessed the quality of each study using the John's Hopkins Nursing Evidence Based Practice tool (JHNEBP).[22] We considered the instances of bias in how to interpret the results because bias can limit external validity.[23]

Effect Measures

Because we chose to accept mixed methods and qualitative studies, we were unable to standardize summary measures, as would be performed in a meta-analysis. We reported measures of effect in tables for those studies in which it was reported. The odds ratio was the preferred measure of effect, but we also collected measures reported as Cohen's d. These were tabulated and reported.

Synthesis Methods

A thematic analysis was performed after data extraction was completed.[21] This procedure helps makes sense of the data collected through data extraction. Although this technique is often used in qualitative research, its use in quantitative research is well established in the literature.[24–26]

Reporting Bias Assessment

The overall ratings of quality from the JHNEBP provide us with an assessment of the applicability of the cumulative evidence by identifying the strength and quality of evidence. Each reviewer recorded observations of bias on the standardized spreadsheet.

Additional Analyses and Certainty Assessment

We performed a narrative analysis of the observations to convert them into themes.[21] We calculated frequency of occurrence and reported these in affinity matrices. The frequency does not imply importance: only the probability of occurrence in the group of articles for analysis. The reported frequency also provides confidence in the data analyzed.

Results

Study Selection

Figure 1 illustrates the article selection process, to include the inclusion and exclusion criteria from four databases plus one targeted article search. A kappa statistic was calculated based on the level of agreement between authors, (k=0.99, near perfect agreement).[27,28] The initial search yielded 113,698 results. A series of filters (full text, human subjects, English language, peer-reviewed, academic journals, and exclude reviews), abstract screening, and a brief full article examination reduced the final group to 30. About 42% of those rejected were due to the age of the participants. These 30 studies generated from 11 different countries, but most were from the US (14/30, 47%), China (4/30, 13%), the UK (2/30, 7%), Korea (2/30, 7%), and Bangladesh (2/30, 7%). Eastern and Western medicines are different in their approach, but they were included to provide a comprehensive overview of interventions and their level of success.

Study Characteristics

Following the PRISMA (2020) checklist, Table 1 was created to summarize the characteristics of each article analyzed (participants, intervention, comparison, outcomes, study design, PICOS). Of the 30 articles analyzed, over the 2.5 year period, 100% were older adults over 50, 100% implemented a form of mHealth for the intervention (mHealth app 37%, mHealth Short Message Service (SMS) 27%, mHealth plus remote monitoring 17%, mHealth plus telemedicine 13%, mHealth app plus SMS 7%). Of the 30 studies, 15 (50%) were randomized control trials (RCT), 6 (20%) were qualitative, 3 (10%) were observational and 3 were quasi-experimental, 2 (7%) were true experiments, and 1 was a focus group. Slightly less than half originated in the United States (14/30, 47%). Studies are listed in chronological order and alphabetically: 2020 (n=19),[29–47] 2021 (n=8),[48–55] 2022 (n=3).[56–58] For each study, we extracted the following data fields: participants, intervention, comparison (to control or other group), medical outcomes, study design, sample size, bias within study, country of origin, statistics used, patient satisfaction, quality associated with intervention, barriers to adoption, strength of evidence, and quality of evidence. This was performed as a way to summarize study characteristics in a manner established in the literature. Results varied across studies. Twenty-five out of 30 (83%) articles found an improvement in at least one area studied, (eg, HbA1C), but the improvement was not always statistically significant. While mHealth apps were effective at helping diabetes patients manage their disease, some apps required manual entry of data, which discouraged users from using it. The intervention of mHealth SMS showed consistently improvement across multiple focus areas: BMI, weight loss, exercise, diet, disease awareness, HbA1C, and healthy behaviors. Similar results were also observed with mHealth plus telemedicine coaching. Additional explanation of the results will be provided below.

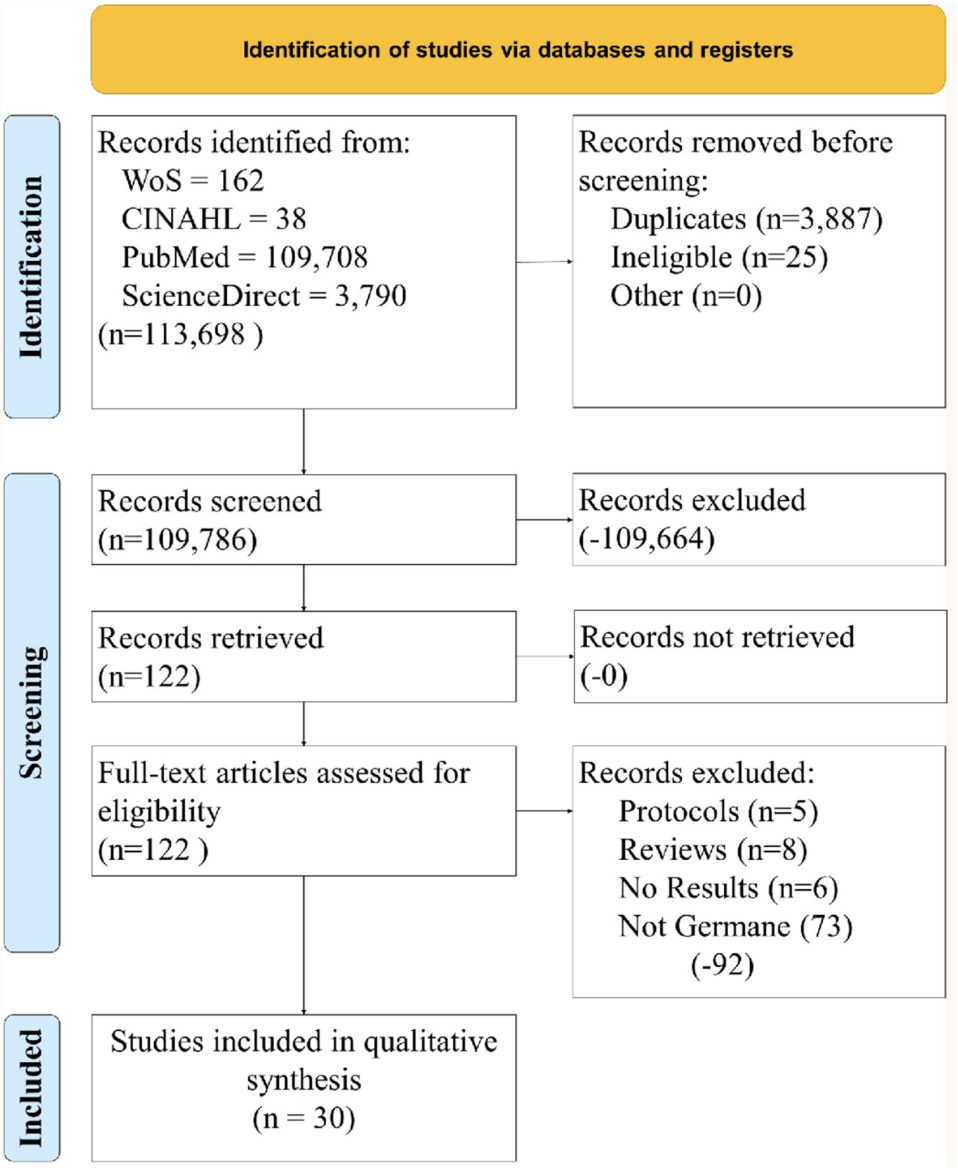

Figure 1 PRISMA diagram—article selection process.
Notes: PRISMA figure adapted from Page MJ, McKenzie JE, Bossuyt PM et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71. Creative Commons.[20]

Risk and Reporting of Bias in Studies

Reviewers used the JHNEBP quality assessment tool identified the following the strength and quality of evidence. Of the 30 articles analyzed, 18/30 (60%) were strength I (the highest rating) because they were either RCTs or true experiments. 10/30 (33%) were type III (qualitative or observational) and 2/30 (7%) were type II (quasi-experimental). Most studies used large samples (average 1022) reported consistent results with definitive conclusions, and used adequate controls, so the quality of evidence was strong, or Type A (23/30, 77%) and the remainder used smaller but adequate samples (7/30, 23%). Studies of type C or strength below III were not used for analysis. Reviewers also made note of bias within and among the studies. The most common bias was selection bias (27/30, 90%) because most studies used convenience samples in one city or country. The second most common was sample bias (8/30, 27%) because the sample was a majority of one gender or race. Selection and sample bias affect the external and internal validity of studies, respectively.

Table 1 PICOS

Authors	Participants (Demographics of Group Analyzed)	Experimental Intervention (as Opposed to Traditional Care)	Results (Compared To Control Group)	Medical Outcomes Reported	Study Design
Alkawaldeh et al[28]	Older adults, average age 68.65, 58% female, 75% white	Tablet-based application ASSISTwell	Users of ASSISTwell had higher PDSMS scores than the control, showing mHealth intervention improves self-management skills.	Improved Blood Glucose Level (BGL) not statistically different between groups. Improved perceived self-management.	Quasi-experimental
Bohm et al[29]	Older adults, average age 50.4, 57% female	mHealth app (Glooko diabetes app)	No control group. Technology acceptance was strong. Women used the app more frequently for exercise.	Not reported	Observational
Heo et al[30]	Older adults, average age 70.9, 68% male	mHealth app (screening to prevent strokes)	No control group. App positively identified patients at risk for atrial fibrillation	App positively identified patients at risk for atrial fibrillation	Observational
Howland et al[31]	Older adults	Remote monitoring	Patients in the intervention group received more education and communication with providers than the control. Exercise and overall self-care increased.	HbA1C decreased	RCT
Jiwani et al[32]	Older adults	mHealth and wearable sensors	Participants expressed high acceptability of both mHealth and the Fitbit technology. Anecdotes about how the intervention has improved different areas of their life (quality, social support, and behavior change)	Not reported	Focus Group
Kim et al[33]	Older adults > 65. average age 68, 66.7% female	mHealth logging and tracking + 1-on-1 coaching	Coaches triggered reflections on users' habits, facilitated self-evaluations, tailored programs to match lifestyles.	Users in the intervention group lost weight.	Qualitative
Nelson et al[34]	Older adults, average age 55.8. 55% female, 41% non-white	SMS (REACH)	Engagement was high in the intervention group. Self-management improved	Self-management improved due to SMS messages	RCT
Owolabi et al[35]	Older adults	SMS education	Not statistically different results, but the intervention showed an increase in medication adherence, diet and exercise.	Improved medicine adherence, low level of adherence to diet and exercise messages	RCT
Sittig et al[36]	Older adults	mHealth app (capABILITY)	Improved diet, exercise, and BGL	Improved diet, exercise, and BGL	RCT
Staite et al[37]	Older adults	SMS vs web-based	No statistically significant differences	Improved diet, exercise, and BGL	RCT
Steinman et al[38]	Older adults, average age 55.9, 63% female	SMS	No control group. Participants preferred voice messages over text-messages (likely due to low literacy) Also, participants preferred a jovial female voice over a formal masculine voice. Researchers also found that participants preferred messages around dinner time so they could discuss this with friends and family	Improved self-management, diet, weight management, exercise, smoking and drinking, BGL, and medication adherence	Qualitative
Tong et al[39]	Older adults, average age 63, 75% male	mHealth and telemedicine	No control group	Not reported	Qualitative
Toro-Ramos et al[40]	Older adults	mHealth	Weight and BMI were significantly lower in the intervention group at 12 months by −1.80 kg (SE 0.81; P=0.01) and −0.58 kg/m2 (SE 0.24; P=0.01), respectively. HbA1c levels showed no difference between the groups at 12 months (0.006%; SE 0.07; P=0.93).	Decrease in weight and BMI, but no statistically different HbA1C at 6 month mark. Decrease in HbA1C at 12 months.	RCT
Wang et al[41]	Older adults, average age 55.1	SMS	Improved self-management behaviors. The SMS intervention successfully improved participants' continuous exercise and weight control. Also, the SMS intervention group had a greater improvement in awareness of diabetes risk factors	Improved weight, diet, BGL	RCT
Xu et al[42]	Older adults	SMS	Increase in self-management behaviors. Reduction in HbA1C and fasting blood glucose, increase in engagement.	Reduction in HbA1C and fasting blood glucose, increase in engagement	RCT
Yang et al[43]	Older adults	mHealth app	Increase in self-management behaviors. Reduction in HbA1C and fasting blood glucose, increase in engagement. For acceptability, participants wore the Fitbit for 40.1 (SD 3.2) days, and 20% (9/45) of participants and 53% (24/45) of participants were prompted by email to charge or sync the Fitbit which is important because this indicates usage.	Reduction in HbA1C and fasting blood glucose, increase in engagement	RCT
Yang et al[44]	Older adults	mHealth app. Digital phenotype developed to predict level of engagement with mHealth apps.	No control group. Younger, nonwhite, low income, female with higher HbA1C more likely to be in low and waning engagement group	Not reported	Observational
Yasmin et al[45]	Older adults	mHealth apps and SMS	No control group. Participants expressed positively about SMS messages concerning diet, exercise, medication, smoking cessation, and other lifestyle behaviors.	Not reported	Qualitative

(*Continued*)

Table 1 (Continued).

Authors	Participants (Demographics of Group Analyzed)	Experimental Intervention (as Opposed to Traditional Care)	Results (Compared To Control Group)	Medical Outcomes Reported	Study Design
Yasmin et al[46]	Older adults	SMS	Increase in health self-management behavior. Significant improvement in diet, exercise, smoking cessation, and BGL control.	Significant improvement in diet, exercise, smoking cessation, and BGL control.	RCT
Damayanti et al[47]	Older adults, average age 61, 50% male,	SMS	Improved diet, exercise, blood-glucose testing, and foot care	Improved blood-glucose testing, and foot care	Quasi-experimental
Fu et al[48]	Older adults	mHealth apps and SMS	Improved self-management behaviors	Improved self-management behaviors	Qualitative
Jia et al[49]	Older adults	mHealth enabled hierarchical diabetes management	Overall improvement of HbA1C, but no statistically significant differences in weight changes.	Improved HbA1C	RCT
Lee et al[50]	Older adults	mHealth apps and coaching	Improved self-management behaviors	Improved HbA1C	RCT
Lewinski et al[51]	Older adults	mHealth	No control group	Not reported	Qualitative
Li et al[52]	Older adults	mHealth app and wearable sensor	Intervention group showed larger increase in cardiopulmonary endurance, larger decrease in body fat percentage	Increase in cardiopulmonary endurance, decrease in body fat percentage	RCT
Montero et al[53]	Older adults, average age 56.1, 81% Black, 62% female	Cellular remote monitoring, Biotel system dashboard + telemedicine visits	Statistically significant difference in HbA1C levels between groups as well as user confidence in self-management	Improvement in HbA1C	True experiment
Prabhu et al[54]	Older adults	mHealth app and wearable sensor	More patients used the remote monitoring system during the pandemic than before the pandemic	Adherence to reporting increased during the pandemic	Quasi-experimental
Lin et al[55]	Older adults	mHealth and telemedicine	Decrease in BMI, fasting blood glucose, HbA1C, cholesterol, and blood pressure. Hypoglycemia occurred in both groups.	Decrease in BMI, fasting blood glucose, HbA1C, cholesterol, and blood pressure. Hypoglycemia occurred in both groups.	True experiment
Ware et al[56]	Older adults, average age 62, 61% male, 48% white	mHealth and telemonitoring	No significant within- and between-group differences were found for primary and secondary outcomes, however the intervention group saw improvements in self-care behavior.	Improvement in self-care behavior	RCT
Xia et al[57]	Older adults	mHealth (weChat) + eHealth (TangPlan) vs standard care	Decrease in weight, blood pressure, cholesterol, and increase in fasting blood glucose control	Decrease in weight, blood pressure, cholesterol, and increase in fasting blood glucose control	RCT

Results of Individual Studies

Reviewers independently analyzed each article and recorded independent observations commensurate with the objective statement. A thematic analysis was conducted as part of sense making.[21] Each observation that occurred more than once became a theme. Themes were used to summarize the observations, but they did not always match the observation completely. A summary of the themes is tabulated in Table 2. Articles are listed in chronological order. Appendices 1A and B show an observation-to-theme match. Appendix 1c tabulates the additional data extracted from the literature. Additional analysis of the findings is provided below.

Results of Syntheses, Additional Analysis and Certainty of Evidence

The thematic analysis made sense of the data, and themes were tabulated into affinity matrices for analysis. While frequency does not imply importance, it does provide a probability of occurrence in the group of articles for analysis.

When mHealth apps were utilized as the intervention, the most common patient satisfaction theme was that patients were satisfied with the intervention, however, many were discouraged when the app required manual input of data. When the mHealth apps were coupled with wearable sensors, and the data from the sensors were automatically entered into the app, the observation about manual entry went away. These interventions showed improvement in at least one area of observation, but the results were not as strong as other interventions. When mHealth SMS was utilized as the intervention, patients noted that the messages helped them improve their self-care habits. The results, medical outcomes, and quality observations were strong with this intervention. However, when the mHealth SMS was coupled with telemedicine visits to offer coaching, the results were the strongest. Patients developed good self-care behavior, improved

Table 2 Summary of Analysis, Sorted Chronologically by Author

Authors	Intervention Theme	Results Theme	Medical Outcomes Theme	Patient Satisfaction Theme	Quality Theme	Barrier Theme
Alkawaldeh et al[28]	mHealth app	Improved at least one area	Improved at least one area	Users satisfied with mHealth functionality	Self-management skills increased	Must teach users
		Improved self-management /healthy behaviors	Improved self-management			
		Improved blood glucose level/ HbA1C	Improved blood glucose/HbA1C			
Bohm et al[29]	mHealth app	Improved exercise	Not reported	Activity on app increased for those recently diagnosed	Increased monitoring	Manual entry discourages use
		Improved at least one area				
Heo et al[30]	mHealth app	No control group	Increased disease awareness	Not reported	Greater screening for at-risk patients	Must teach users
		App identified patients at risk	Improved at least one area			
Howland et al[31]	mHealth + Remote monitoring	Improved at least one area	Improved at least one area	Users satisfied with mHealth functionality	Increased education of disease	Increases nursing activity
		Increased disease awareness	Increased disease awareness			
		Improved blood glucose level/ HbA1C	Improved blood glucose/HbA1C			
		Improved exercise	Improved physical functioning			
		Improved self-management /healthy behaviors	Improved self-management			
Jiwani et al[32]	mHealth + Remote monitoring	No control group	Improved self-management	Users satisfied with mHealth functionality	Increased education of disease	Not reported
		Improved at least one area			Self-management skills increased	
		Increased access to support				
		Improved self-management /healthy behaviors				
Kim et al[33]	mHealth app	Improved at least one area	Improved at least one area	Travel savings greatly appreciated	Increased connectedness	Must teach users
		Improved weight loss	Improved weight loss			
		Improved self-management /healthy behaviors	Improved self-management		Self-management skills increased	
Nelson et al[34]	mHealth SMS	Improved at least one area	Improved at least one area	Users satisfied with mHealth functionality	Self-management skills increased	Must own text-enabled cell phone
		Improved self-management /healthy behaviors	Improved self-management			Cost of device
Owolabi et al[35]	mHealth SMS	Improved at least one area	Improved at least one area	Users satisfied with mHealth functionality	Increased medication adherence	Must own text-enabled cell phone
		No statistically significant difference	No statistically significant difference		Self-management skills increased	Cost of device
		Improved treatment adherence	Increased disease awareness			
		Improved exercise	Improved physical functioning			
		Improved diet	Improved diet			
Sittig et al[36]	mHealth app	Improved at least one area	Improved at least one area	Users satisfied with mHealth functionality	Self-management skills increased	Must own text-enabled cell phone
		Improved diet	Improved diet		Improved exercise	Must teach users
		Improved exercise	Improved physical functioning		Improved blood glucose/HbA1C	Cost of device
		Improved blood glucose level/ HbA1C	Improved blood glucose/HbA1C		Improved diet	
Staite et al[37]	mHealth SMS	No statistically significant difference	No statistically significant difference	Users satisfied with mHealth functionality	Improved diet	Must own text-enabled cell phone
		Improved diet	Improved diet		Improved exercise	Cost of device
		Improved exercise	Improved physical functioning		Improved blood glucose/HbA1C	Must teach users
		Improved blood glucose level/ HbA1C	Improved blood glucose/HbA1C		Self-management skills increased	
Steinman et al[38]	mHealth SMS	No control group	Improved at least one area	Users satisfied with mHealth functionality	Self-management skills increased	Must own text-enabled cell phone
		Improved at least one area	Improved self-management		Improved diet	Cost of device
		Improved access to support	Improved diet		Improved exercise	Must teach users
		Improved exercise	Improved physical functioning		Improved weight management	
		Improved weight loss	Improved weight loss			
		Improved diet	Improved smoking cessation		Improved smoking cessation	
		Improved blood glucose level/ HbA1C	Improved blood glucose/HbA1C		Increased medication adherence	
		Improved treatment adherence	Improved medication adherence			

(*Continued*)

Table 2 (Continued).

Authors	Intervention Theme	Results Theme	Medical Outcomes Theme	Patient Satisfaction Theme	Quality Theme	Barrier Theme
Tong et al[39]	mHealth + telemedicine	No control group	Not reported	Users were dissatisfied with usefulness	Not reported	Disinterest of users Inconvenience of data entry Must teach users
Toro-Ramos et al[40]	mHealth app	Improved at least one area Improved weight loss Improved BMI Improved blood glucose level/ HbA1C	Improved at least one area Improved weight loss Improved BMI Improved blood glucose/HbA1C	Users satisfied with mHealth functionality	Improved weight management Improved blood glucose/HbA1C	Must teach users Must own smart cell phone Cost of device
Wang et al[41]	mHealth SMS	Improved at least one area Improved self-management /healthy behaviors Improved exercise Improved weight loss Increased disease awareness	Improved at least one area Improved self-management Improved physical functioning Improved weight loss Increased disease awareness	Users satisfied with mHealth functionality	Self-management skills increased	Must own text-enabled cell phone Cost of device Must teach users
Xu et al[42]	mHealth SMS	Improved at least one area Improved self-management /healthy behaviors Improved blood glucose level/ HbA1C Increased communication	Improved at least one area Improved self-management Improved blood glucose/HbA1C	Users satisfied with mHealth functionality	Improved blood glucose/HbA1C Self-management skills increased	Must own text-enabled cell phone Cost of device Must teach users
Yang et al[43]	mHealth app	Improved at least one area Improved self-management /healthy behaviors Improved blood glucose level/ HbA1C Increased communication	Improved at least one area Improved self-management Improved blood glucose/HbA1C	Users satisfied with mHealth functionality	Improved blood glucose/HbA1C Self-management skills increased	Must own text-enabled cell phone Cost of device Must teach users
Yang et al[44]	mHealth app	No control group App identified patients at risk	Not reported	Users satisfied with mHealth functionality	Self-management skills increased	Must own text-enabled cell phone Cost of device Must teach users
Yasmin et al[45]	mHealth app + SMS	No control group Improved at least one area Increased disease awareness	Improved at least one area Increased disease awareness	Users satisfied with mHealth functionality	Self-management skills increased	Must own text-enabled cell phone Cost of device Must teach users
Yasmin et al[46]	mHealth SMS	Improved at least one area Improved self-management /healthy behaviors Improved diet Improved exercise Increased disease awareness Improved blood glucose level/ HbA1C	Improved at least one area Improved self-management Improved diet Improved physical functioning Increased disease awareness Improved smoking cessation Improved blood glucose/HbA1C	Users satisfied with mHealth functionality	Improved diet Improved exercise Improved smoking cessation Improved blood glucose/HbA1C Self-management skills increased	Must own smart cell phone Cost of device Must teach users
Damayanti et al[47]	mHealth SMS	Improved at least one area Improved diet Improved exercise Improved blood glucose level/ HbA1C Improved foot care	Improved at least one area Improved diet Improved physical functioning Improved blood glucose/HbA1C Improved foot care	Users satisfied with mHealth functionality	Improved diet Improved exercise Improved foot care Self-management skills increased	Must own text-enabled cell phone Cost of device Must teach users
Fu et al[48]	mHealth app + SMS	Improved at least one area Improved self-management /healthy behaviors	Improved at least one area Improved self-management	Users satisfied with mHealth functionality	Self-management skills increased	Manual entry discourages use Display and presentation issues

(*Continued*)

Table 2 (Continued).

Authors	Intervention Theme	Results Theme	Medical Outcomes Theme	Patient Satisfaction Theme	Quality Theme	Barrier Theme
Jia et al[49]	mHealth app	Improved at least one area	Improved at least one area	Users satisfied with mHealth functionality	Improved blood glucose/HbA1C	Must own smart cell phone
		Improved blood glucose level/ HbA1C	Improved blood glucose/HbA1C		Self-management skills increased	Cost of device
		Improved exercise	Improved physical functioning			
		No statistically significant difference	No statistically significant difference			Must teach users
Lee et al[50]	mHealth app	Improved at least one area	Improved at least one area	Users satisfied with mHealth functionality	Self-management skills increased	Must own smart cell phone
		Improved blood glucose level/ HbA1C	Improved blood glucose/HbA1C		Improved blood glucose/HbA1C	Cost of device
		Improved self-management /healthy behaviors	Improved self-management			Must teach users
Lewinski et al[51]	mHealth app	No control group	Not reported	Users satisfied with mHealth functionality	Self-management skills increased	Multiple devices complicates monitoring
						Must own smart cell phone
						Cost of device
				Users requested larger fonts and simplified data visualizations		Must teach users
Li et al[52]	mHealth + Remote monitoring	Improved at least one area	Improved at least one area	Users satisfied with mHealth functionality	Increase in cardiopulmonary endurance	Must own smart cell phone
		Improved cardiopulmonary endurance	Improved cardiopulmonary endurance		Improved weight management	Cost of device
		Improved BMI	Improved BMI			Must teach users
Montero et al[53]	mHealth + telemedicine	Improved at least one area	Improved at least one area	Users satisfied with mHealth functionality	Improved blood glucose/HbA1C	Must own smart cell phone
		Improved blood glucose level/ HbA1C	Improved blood glucose/HbA1C		Self-management skills increased	Cost of device
		Improved self-management /healthy behaviors	Improved self-management			Must teach users
Prabhu et al[54]	mHealth + Remote monitoring	Improved at least one area	Improved at least one area	Users satisfied with mHealth functionality	Increased connectedness	Must own smart cell phone
						Cost of device
		Improved self-management /healthy behaviors	Improved self-management			Must teach users
Lin et al[55]	mHealth + telemedicine	Improved at least one area	Improved at least one area	Users satisfied with mHealth functionality	Improved weight management	Must own smart cell phone
		Improved BMI	Improved BMI		Improved blood glucose/HbA1C	Cost of device
		Improved blood glucose level/ HbA1C	Improved blood glucose/HbA1C		Improved cholesterol	Must teach users
		Improved cholesterol	Improved cholesterol		Improved blood pressure	
		Improved blood pressure	Improved blood pressure			
Ware et al[56]	mHealth + Remote monitoring	No statistically significant difference	No statistically significant difference	Users satisfied with mHealth functionality	Self-management skills increased	Must own smart cell phone
		Improved at least one area	Improved at least one area			Cost of device
		Improved self-management /healthy behaviors	Improved self-management			Must teach users
Xia et al[57]	mHealth + telemedicine	Improved at least one area	Improved at least one area	Users satisfied with mHealth functionality	Improved weight management	Must own smart cell phone
		Improved weight loss	Improved weight loss		Improved blood pressure	Cost of device
		Improved blood pressure	Improved blood pressure		Improved cholesterol	Must teach users
		Improved cholesterol	Improved cholesterol		Improved blood glucose/HbA1C	
		Improved blood glucose level/ HbA1C	Improved blood glucose/HbA1C		Self-management skills increased	

in weight loss, diet, exercise, blood glucose levels, cholesterol, blood pressure, and foot care. This intervention showed the strongest results.

Three sections of themes are similar, but they were created for different audiences. The section "results" is generic, and it includes results of studies (compared to a control group, where appropriate) that are both administrative, clinical, and patient-centered. The section "medical outcomes" is designed for the practitioner. The section "Quality" is designed for the administrator. While there are some repeats in these three sections, they are tailored for the specific audiences and some verbiage changes for them.

Results of Studies, Compared with the Control Group

Table 3 tabulates the Result themes and individual observations. Reviewers made some general observations. In 25/30 (83%) articles, an improvement in at least one area was observed, but the improvement was not always statistically significant. This accounted for 25/107 (23%) of the observed themes or observations.[29,30,32–37,39,41–43,45–51,53–58] Improved self-management behaviors appeared in 14/107 (13%) of the occurrences.[29,32–35,42,43,45,47,49,51,54,55,57] Patients who used mHealth as interventions in their care demonstrated improved blood glucose level (BGL)/HbA1C, included fasting blood glucose (FBG). This theme appeared in 15/107 (14%) of the occurrences.[29,32,37–39,41,43,45,47,48,50,51,54,56,58] The theme "improved exercise" appeared in 10/107 (9%) of the occurrences. The themes "improved diet"[36–39,47,48] and "improved weight loss"[34,39,41,42,58] each appeared in 6/107 (6%) of the occurrences. The theme "increased disease awareness" appeared in 4/107 (4%) of the occurrences. Improved BMI appeared in 3/107 (3%) occurrences. The themes "increased communication",[43,45] "improved blood pressure",[56,58] "improved cholesterol",[56,58] "improved treatment adherence",[36,39] and "app identified patients at risk",[31,44] each occurred in 2/107 (2%) occurrences. The following observations could not be categorized into themes: "increased access to support", "improved cardiopulmonary endurance", and "improved foot care."[33,48,53]

Medical Outcomes Commensurate with the Intervention

Table 4 tabulates the medical outcome themes and observations. Like in the results themes, reviewers made some general observations: the use of mHealth interventions showed improvements in at least one clinical area in 24/30

Table 3 Results Themes and Observations

Results Themes and Observations	Frequency
Improved at least one area[28,29,31–36,38,40–42,44–50,52–57]	25
Improved blood glucose level/HbA1C[28,31,36–38,40,42,44,46,47,49,50,53,55,57]	15
Improved self-management/healthy behaviors[28,31–34,41,42,44,46,48,50,53,54,56]	14
Improved exercise[29,31,35–38,41,46,47,49]	10
No control group[30,32,38,39,43,45,51]	7
Improved diet[35–38,46,47]	6
Improved weight loss[33,38,40,41,57]	5
No statistically significant difference[35,37,49,56]	4
Increased disease awareness[31,45,46,56]	4
Improved BMI[40,50,55]	3
Increased communication[42,44]	2
Improved blood pressure[55,57]	2
Improved cholesterol[55,57]	2
Improved treatment adherence[35,38]	2
App identified patients at risk[30,43]	2
Increased access to support[32]	1
Improved cardiopulmonary endurance[52]	1
Improved foot care[47]	1
	106

Table 4 Medical Outcomes Themes and Observations

Medical Outcome Themes	Frequency
Improved at least one area[28,30,31,33–36,38,40–42,44–50,52–57]	24
Improved self-management[28,31–34,38,41,42,44,46,48,50,53,54,56]	15
Improved blood glucose/HbA1C[28,31,36–38,40,42,44,46,47,49,50,53,55,57]	15
Improved physical functioning[31,35–38,41,46,47,49]	9
Improved diet[35–38,46,47]	6
Increased disease awareness[30,31,35,41,45,46]	6
Improved weight loss[33,38,40,41,57]	5
Not reported[29,39,43,51]	4
No statistically significant difference[35,37,49,56]	4
Improved BMI[40,52,55]	3
Improved cholesterol[55,57]	2
Improved smoking cessation[38,46]	2
Improved blood pressure[55,57]	2
Improved medication adherence[38]	1
Improved foot care[47]	1
Improved cardiopulmonary endurance[52]	1
	100

articles (60%),[29,31,32,34–37,39,41–43,45–51,53–58] and there was an improvement in self-management in 15/30 articles (50%).[29,32–35,39,42,43,45,47,49,51,54,55,57] The theme "improved blood glucose/HbA1C" appeared 15/100 (15%) of the occurrences.[29,32,37–39,41,43,45,47,48,50,51,54,56,58] The theme "improved physical functioning" occurred 9/100 (9%) occurrences.[32,36–39,42,47,48,50] Improved diet[36–39,47,48] and increased disease awareness[31,32,36,42,46,47] each appeared 6/100 (9%) occurrences. Improved weight loss occurred 5/100 (5%) of the occurrences.[34,39,41,42,58] Improved BMI occurred 3/100 (3%) of the occurrences.[41,53,56] The themes "improved cholesterol",[56,58] "improved smoking cessation",[39,47] and "improved blood pressure",[56,58] each occurred 2/100 (2%) of the occurrences. Finally, three observations could not be categorized into themes: "improved medication adherence", "improved foot care", and "improved cardiopulmonary endurance."[39,48,53]

Quality Themes and Observations Commensurate with the Intervention

Table 5 tabulates the Quality themes and observations. Of these observations, the "increase in self-management skills" is the most significant, appearing 21/80 (26%) of the occurrences.[29,32–39,43–46,50,51,54,55,57,58] Improved blood glucose/HbA1C appeared in 15/80 (19%) of the occurrences.[29,32,37–39,41,43,45,47,48,50,51,54,56,58] Improved exercise[32,36–39,42,47,48,50] appeared 9/100 (9%), and improved weight management[34,39,41,42,53,56,58] appeared 8/100 (8%) of the occurrences. Improved diet[36–39,47,48] appeared 6/100 (6%) and increased education of disease[32,33,36,42,47] occurred 5/100 (5%) of the occurrences. The following themes each appeared 2/100 (2%) of the occurrences: "increased medication adherence",[36,39] "improved smoking cessation",[39,47] "improved blood pressure",[56,58] "improved cholesterol",[56,58] and "increased connectedness." The following observations could not be categorized into a theme: "improved foot care",[48] "increased monitoring", "greater screening for at-risk patients", and "increase in cardiopulmonary endurance."[30,31,48,53]

The most commonly identified theme for patient satisfaction was that patients/participants were satisfied with the functionality of mHealth. This theme appeared 26/31 (84%) of the occurrences.[29,32,33,35–39,41–58] Four other observations were identified, but they could not be fit into themes: "Activity on app increased for those recently diagnosed with diabetes", "users were dissatisfied with usefulness", "travel savings were greatly appreciated because the mHealth app prevented them from driving into the clinic", and "users requested larger fonts and simplified data visualizations."[30,34,40,52]

Table 5 Quality Themes and Observations

Quality Themes and Observations	Frequency
Self-management skills increased[28,31–38,42–45,49,50,53,54,56,57]	21
Improved blood glucose/HbA1C[28,31,36–38,40,42,44,46,47,49,50,53,55,57]	15
Improved exercise[31,35–38,41,46,47,49]	9
Improved weight management (including BMI)[33,38,40,41,52,55,57]	8
Improved diet[35–38,46,47]	6
Increased education of disease[31,32,35,41,46]	5
Increased medication adherence[35,38]	2
Improved smoking cessation[38,46]	2
Improved blood pressure[55,57]	2
Improved cholesterol[55,57]	2
Increased connectedness	2
Not reported	2
Improved foot care[47]	1
Increased monitoring[29]	1
Greater screening for at-risk patients[30]	1
Increase in cardiopulmonary endurance[52]	1
	80

Table 6 Themes and Observations for Barriers to the Adoption of mHealth Interventions

Barrier Themes and Observations	Frequency
Must teach users[28,30,33,36–47,49–57]	24
Cost of device[34,35,37,38,40–47,50,51,53–57]	22
Must own text-enabled cell phone[18,34–38,41,42,44,45,47]	11
Must own smart cell phone[40,46,49–57]	11
Manual entry discourages use[29,48]	2
Disinterest of users[39]	1
Inconvenience of data entry[39]	1
Display and presentation issues[48]	1
Multiple devices complicates monitoring[51]	1
Increases nursing activity[31]	1
Not reported[32]	1
	76

Table 6 tabulates the themes and observations associated with barriers to adoption of mHealth interventions for the management of diabetes. The most common themes identified were associated with the necessity to acquire a mobile device in order to use it as an intervention. This includes the cost of acquisition and the training of the users. Teaching users occurred the most often, 24/76 (32%).[29,31,34,37–48,50–58] Cost of device appeared 22/76 (29%) of the occurrences.[35,36,38,39,41–48,51,52,54–58] Must own a text-enabled cell phone[18,35–39,42,43,45,46,48] or a smart cell phone each occurred 11/76 (14%).[41,47,50–58] Manual entry of data discourages use of the app appeared 2/76 (3%) of the occurrences.[30,49] The following observations could not be categorized into a theme: "Disinterest of users", "inconvenience of data entry", "display and presentation issues", "multiple devices complicates monitoring", and nursing activities increase as a result of the intervention."[32,40,49,52]

Discussion

Summary of Evidence

This research found that 83% of the articles analyzed reported a positive outcome in at least one area of focus.[29,30,32–37,39,41–43,45–51,53–58] mHealth SMS helps patients develop health habits and increase their level of self-care.[35,36,38,42,43,46–49,59] The most significant finding of this research is that mHealth SMS coupled with telemedicine for coaching yields positive results for BMI, weight loss, exercise, foot care, diet, and overall self-care.[40,54,56,58]

Healthcare providers can leverage mHealth SMS services to help diabetes patients create health habits and improve self-care for older adults. Coupled with telemedicine visits, provider teams can coach diabetes patients into long-term, self-care habits and decrease mortality incident to the disease. mHealth SMS coupled with telemedicine not only serves as a preventative for future diabetes-related ailments, but it also increases the health and longevity of patients who have suffered with diabetes for years.

Administrators can view the expense of mHealth SMS and telemedicine interventions as both preventative and ongoing maintenance of diabetes. These measures greatly increase the self-management of diabetes patients. Screening tools can be employed to identify at-risk patients and begin to change their habits early.

Developers should note the continued observations about manual entry, small fonts, and complicated data visualizations. Manual entry of data discourages users from using the app.[49] mHealth applications should fully interface with the wearable sensors and transmit data to the provider team and electronic health record. Fonts must be large enough for older adults to comfortably view, and data visualizations should be simple enough to provide immediate feedback and, if necessary, compel action.[52]

Future research should explore mHealth combinations more thoroughly. Does mHealth apps plus telemedicine coaching yield as strong of results? Do mHealth apps, SMS, and telemedicine yield strong results? Also, cohort studies would be helpful to determine if the change in self-management is transitory or long term. This study analyzed Type 2 diabetes, instead of Type 1. Future research should focus on Type 1 diabetes. Historically, Type 1 diabetes has only comprised less than 10% of the diabetes population, but COVID-19 has caused a large surge in this population. Type 1 diabetes has always been a significant disease to study, and COVID-19 has raised its importance.

Limitations

A limitation of this review is the short time-frame chosen for publication of articles. We chose 2.5 years due to the plethora of results that occurred in our initial search using 5 or 10 years. Analyzing additional articles may have yielded new results or additional iterations of the same results. However, technology advances rapidly, and more recent articles will reflect current technology and capabilities of the same. Additionally, our search string focused on MeSH terms (with the exception of "smartphone"), which might have omitted studies not indexed with MeSH hierarchy. The term "smartphone" was used to control for this issue, however, we may still have not identified all studies.

Including grey literature may have also yielded different results. Our team chose to omit grey literature because opinions are not always based on study results. We chose to include research studies with strong designs. As a result of that decision, half of the articles analyzed in this review were RCTs.

Conclusion

The broad implication of this study is that mHealth SMS helps educate persons with diabetes and when coupled with telemedicine coaching, it yields very strong clinical and administrative results. These particular interventions are not costly, do not adversely affect patient satisfaction, and may result in fewer hospitalizations for diabetes related ailments. Most people own text-enabled phones, but not as many own smart phones. Unless mHealth apps fully interface with remote sensors and transmit data to care teams, patients will lose patience with any manual-entry and will abandon it. SMS, however, provides quick, simple education and reminders to help develop health habits and encourage self-care.

Other Information

This review is conducted in accordance with the Kruse Protocol for writing a systematic review.[19] It is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis.[20] This review is registered with PROSPERO: registration number CRD42021266568.

Abbreviations

BGL, Blood glucose level; GLM, General Linear Model; JHNEBP, Johns Hopkins Nursing Evidence Based Practice (tool); PDSMS, Perceived diabetes self-management scale; PICOS, Participants, intervention, comparison (to control), outcomes (medical), and study design; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RCT, Randomized controlled trial; SMS, Short Message Service.

Ethics Disclosure

This work was exempted from normal IRB processes, as it is a systematic review. The research was conducted in accordance with the Declaration of Helsinki.

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