

## Technology and diabetes self-management: An integrative review

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### Abstract

Technology can be used to supplement healthcare provider diabetes care by providing both educational and motivational support. Education can be provided using technology allowing patients to learn new practices and routines related to diabetes management. Technology can support daily diabetes self-management activities including blood glucose monitoring, exercising, healthy eating, taking medication, monitoring for complications, and problem-solving. This article describes an integrative review conducted to evaluate the types of technology being used to facilitate diabetes self-management and

the effect of that technology on self-management and diabetes outcomes for adults living with type 2 diabetes mellitus. A literature review was conducted by searching Medline, PubMed, and Psych INFO databases using the search terms: diabetes self-management, technology, type 2 diabetes, smartphones, cell phones, and diabetes mellitus covering the years from 2008-2013. Articles relying on secondary data (editorials, systematic reviews) and articles describing study protocol only were excluded. Fourteen studies including qualitative, quasi-experimental, and randomized controlled trial designs were identified and included in the review. The review found that technological interventions had positive impacts on diabetes outcomes including improvements in hemoglobin A1C levels, diabetes self-management behaviors, and diabetes self-efficacy. Results indicate that technological interventions can benefit people living with diabetes when used in conjunction with diabetes care delivered by healthcare providers.

**Key words:** Diabetes mellitus; Diabetes self-management; Type 2 diabetes mellitus; Technology; Integrative review

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**Core tip:** Technology may be used to support diabetes self-management. Both mobile phone and internet-based technological interventions have been found to support self-management behaviors of people living with diabetes. Technology can extend the reach of diabetes self-management to patient's communities and homes, provide for individualized care, and provide just-in-time information.

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## INTRODUCTION

Using technology to facilitate diabetes self-management is not a new idea, but as patients become more technologically savvy, devices become more available, and new technologies emerge, the variety of technological self-management strategies increases. Recent reports indicate that 90% of Americans have cellular phones and 58% of American adults have a smartphone. Among racial groups, Caucasians and African Americans have equal percentages of ownership (90%), while Hispanic Americans have a 92% ownership percentage<sup>[1]</sup>.

Technology can be used to supplement healthcare provider diabetes care by providing both educational and motivational support. Technology can extend the reach of diabetes education and support when primary care resources are insufficient or patient resources and access to care are limited<sup>[2]</sup>. Patients may have difficulty scheduling and attending diabetes education classes or meeting regularly with a diabetes educator due to time, financial, or other constraints<sup>[3]</sup>. Education can be provided using technological resources so that patients learn new practices and routines related to diabetes management. Technology can support the daily diabetes self-management activities of blood glucose monitoring, exercising, healthy eating, taking medication, monitoring for complications, and problem-solving. Visual feedback of clinical information, including these self-management activities, improves patients' ability to see how diabetes is affected by their behaviors and promotes decision-making and problem-solving. Monitoring of self-management behaviors can be motivational and allows for more frequent contact between patients and healthcare providers. This can lead to necessary changes in self-management behaviors and treatment plans<sup>[4]</sup>.

The purpose of this integrative review is to evaluate the types of technology being used to facilitate diabetes self-management and the effect of that technology on self-management and diabetes outcomes for adults living with type 2 diabetes mellitus. The paper identifies technological methods for self-management, outcomes from use of technology in self-management, and future recommendations for the development of technology in diabetes self-management.

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## RESEARCH

Articles were identified by searching Medline, PubMed, and Psych INFO databases using the search terms: diabetes self-management, technology, type 2 diabetes, smartphones, cell phones, and diabetes mellitus covering the years from 2008-2013. Articles relying on secondary data (editorials, systematic reviews) and articles describing study protocol only were excluded. Fourteen studies including qualitative, quasi-experimental, and randomized controlled trial designs were identified and included in the review. A summary of the reviewed articles is provided in Table 1.

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## MOBILE PHONES

Evidence suggests that mobile health applications may be used to deliver health services and self-management tools and overcome barriers to provider access<sup>[5]</sup>. Mobile phones can offer alternatives to in-person diabetes intervention delivery and support<sup>[6]</sup>. Mobile phones provide patients the ability to process and communicate data in real time. A meta-analysis of 22 intervention studies found that mobile phone interventions led to statistically significant improvements in glycemic control and self-management<sup>[7]</sup>. A Cochrane review of computer-based diabetes self-management interventions found a small beneficial effect on blood glucose control with a larger effect noted in mobile phone interventions. Reviewers concluded that mobile phone interventions may be more effective due to convenience, increased contact with the intervention, and cues and feedback provided through the phone<sup>[8]</sup>.

Six of the studies examined in this review utilized a mobile phone intervention. A pilot study qualitatively evaluated a disease management program utilizing mobile phones and gaming systems for individuals living with type 2 diabetes<sup>[9]</sup>. Participants uploaded blood glucose readings using a smartphone, received charts with blood glucose daily, weekly, and monthly trends, emailed or text-messaged healthcare providers with questions, and received reminders and messages about self-management. Qualitatively, participants reported that connecting with a healthcare provider through email was beneficial, but an initial face-to-face meeting made the email communication more meaningful. Uploading data from glucose meters to visualize trends was also beneficial for most participants. They felt that the graphs enabled them to see how their exercise and eating patterns had affected blood glucose. Participants also felt that the intervention program promoted their own general health awareness. Most participants did indicate frustration with the smartphones due to difficulty using the phone. One participant recommended using phones with which patients are already familiar for future studies. Overall, the study results indicate that mobile phones can be effective in assisting people with diabetes self-management. Personal contact with healthcare providers should be included in technological interventions and participants should be included in the decision of which type of technology to be used<sup>[9]</sup>.

A second study piloted an intervention to test the feasibility of an automated, two-way text messaging system to promote blood glucose monitoring in teenagers and young adults with diabetes<sup>[10]</sup>. Participants were randomized to receive messages *via* cell phone text messaging or email for a three month time period. Reminders were sent to check blood glucose and if no response occurred, a second reminder was sent. After the blood glucose value was submitted, a positive feedback message was sent. If the value was out of range, a warning to take action and recheck blood glucose was sent. Of the 40 participants who enrolled in

Table 1 Summary of reviewed articles

Ref.	Technology	Study purpose	Brief description of intervention	Major study results
Arsand <i>et al</i> <sup>[11]</sup>	Mobile phones	Qualitative evaluation of a mobile system for monitoring of blood glucose, nutrition habits, and physical activity as motivation for increasing and benefitting from these self-management behaviors in patients with type 2 diabetes	Participants assisted with development and testing of the mobile phone application. The application included blood glucose monitoring, a step counter that downloaded to the phone, and software for recording food habits and providing feedback on how users performed in relation to their own personal goals	Participant feedback demonstrated good usability of the system and several participants made adjustments in blood glucose, food habits, and/or physical activity based on the tracked self-management behaviors
Avdal <i>et al</i> <sup>[15]</sup>	Internet-based education program	Evaluation of the effect of providing internet-based diabetes education to individuals with type 2 diabetes	Participants in the intervention group viewed individualized diabetes education, asked questions of researchers, and monitored daily blood glucose levels using the internet-based system. Control group participants received education from a diabetes nurse in a clinic setting	After six months, HA1C levels in the intervention group significantly decreased and rates of health check attendance significantly increased. No differences in HA1C or health check attendance were noted for the control group
Fisher <i>et al</i> <sup>[16]</sup>	Internet-based diabetes self-management improvement program	Comparison of effectiveness of internet-based, CASM, CAPS, and computer-administered minimal support interventions	Participants in the CASM group received an internet-based diabetes self-management improvement program that included education, goal-setting, feedback from healthcare providers, and periodic phone calls to monitor progress. CAPS participants received the same plus a 60 min in person intervention to discuss problem-solving therapy related to diabetes distress. The minimal support intervention included computer-delivered health risk appraisal and diabetes information and phone calls from healthcare providers to answer questions about the information	Significant decreases were noted for diabetes distress and significant improvements in healthy eating, physical activity, and medication adherence in all three conditions, with no significant between-group differences
Glasgow <i>et al</i> <sup>[2]</sup>	Internet based DSMP	Comparison of an internet-based DSMP, internet-based DSMP with additional support, and enhanced usual care on healthy eating, physical activity, medication-taking, HA1C, body mass index, lipids, blood pressure, and psychosocial factors	Participants were randomized to one of the three groups. The internet-based DSMP participants used a website to select individual goals related to medication adherence, physical activity, and food choices, record progress, create action plans, identify barriers to self-management, and choose problem-solving strategies. Participants in the internet-based DSMP with additional support group received the above and two follow-up phone calls and three 120 min group sessions with other study participants	Internet conditions improved health behaviors significantly compared to usual care over the 12-mo period. No significant differences were noted between the two internet-based groups. All conditions improved moderately on biological and psychosocial outcomes
Hanauer <i>et al</i> <sup>[10]</sup>	Mobile phones	Pilot study for feasibility of a fully automated, two-way text messaging system to encourage increased blood glucose monitoring	Participants were randomized to receive electronic reminders to check blood glucose levels <i>via</i> mobile phone text messaging or email reminders. Participants determined the frequency and timing of reminders. Reminders were sent to check blood glucose. After entering the value, users received motivational feedback and, if the value was out of range, a warning to take appropriate action was sent. Participants could also receive daily diabetes facts to the mobile phone or email	Compared to the email group, participants in the mobile phone group received more reminders and responded with blood glucose results significantly more often. During the first month, mobile phone group participants submitted twice as many blood glucose values as email users
Lim <i>et al</i> <sup>[12]</sup>	Mobile phones	Improve glycemic control without hypoglycemia in elderly people living with type 2 diabetes using patient-specific messages and reminders delivered to mobile phones	All participants received diabetes education and then were randomly assigned to intervention, routine care, or SMBG groups. Participants in the intervention group received glucometers with a public switched telephone network-connected cradle that automatically transferred blood glucose results to a hospital-based server. Once the data was transferred to the server, an automated system generated and sent patient-specific messages by mobile phone. Routine care participants did not receive an intervention and were told to follow-up with their current medical care. SMBG participants were told to measure blood glucose at least eight times per week	After 6 mo of follow-up, HA1C was significantly decreased from 7.8 to 7.4 in the intervention group and from 7.9 to 7.7 in the SMBG group, compared with 7.9 to 7.8 in the control group. The proportion of patients with HA1C < 7% without hypoglycemia was 30.6% in the intervention group, 23.4% in the SMBG group, and 14.0% in the control group

Lorig <i>et al</i> <sup>[127]</sup>	Internet-based self-management program	Evaluation of effect of an internet-based DSMP on HA1C, diabetes symptoms, exercise, self-efficacy, and patient activation	Participants were randomized to the internet-based program, the internet-based program with e-mail reinforcement, or a usual care control group. The internet-based program consisted of six asynchronous educational sessions, weekly learning activities, discussion boards, and individualized action plans for self-management. Participants in the reinforcement group received the intervention followed by an online discussion group	At 6 mo, HA1C, patient activation, and self-efficacy were significantly improved for program participants compared with usual care control subjects. There were no changes in other health or behavioral indicators. The subgroup with initial HA1C > 7% demonstrated greater significant improvement in HA1C. The reinforcement intervention showed no additional improvements over the intervention alone
Lyles <i>et al</i> <sup>[129]</sup>	Mobile phones and gaming system	Qualitative evaluation of a disease management program utilizing mobile phones and gaming systems for individuals living with type 2 diabetes	Participants received a smartphone to upload blood glucose values and email or text message with a healthcare provider and a gaming system to gain access to a shared medical record that provided summaries of clinical information related to diabetes	Participants expressed frustration with using cell phones and gaming system, but liked collaborating with a healthcare provider on uploaded glucoses and receiving automatic feedback on blood glucose trends
Noh <i>et al</i> <sup>[128]</sup>	Internet-based information system for computers and mobile phones	Evaluation of the effect of a computer and mobile phone accessible internet-based system on blood glucose control	A web-based information system for mobile phone users and a website for Internet users provided diabetes education. Participants in this group were compared to a control group receiving conventional diabetes education	HA1C and postprandial glucose levels were significantly decreased in the intervention group, but not in the control group. There was a significant relationship between the change in HA1C and the frequency of web-based system access
Nundy <i>et al</i> <sup>[123]</sup>	Mobile phones	Qualitative exploration of mechanisms by which a text-message based diabetes program affected self-management among African-Americans living with type 2 diabetes	Participants completed a 4-wk text message based diabetes program in which they received text message reminders about diabetes self-management	Themes that emerged from the study included self-awareness and control of diabetes, reinforcement of success in managing diabetes, acceptance and awareness of seriousness of diabetes, and caring and support
Pacaud <i>et al</i> <sup>[129]</sup>	Internet-based system to provide education for newly diagnosed people with type 2 diabetes	Comparison of three varied media educational systems on diabetes knowledge, self-efficacy, and diabetes self-management activities	Participants were randomly assigned to either the web interactive group who received electronic education and virtual appointments using both synchronous and asynchronous communication, the web static group who received electronic education and virtual appointments using asynchronous communication, or the control group who received face-to-face education and synchronous and asynchronous communication	All three groups had similar improvements in diabetes knowledge, self-efficacy, and diabetes self-care activities. Independent of which group subjects were randomized to, findings were significant when examining correlation between website usage and outcomes: a higher total use was significantly associated with a higher diabetes knowledge score, a higher total diabetes self-efficacy score, and lower HA1C by final study visit
Quinn <i>et al</i> <sup>[144]</sup>	Mobile phones	Evaluation of a diabetes coaching system that used mobile phones and patient-provider portals for individualized treatment and communication	Participants were randomly assigned to one of three treatment conditions or a usual care control group. Participants utilized a patient-coaching system consisting of a mobile diabetes management software application that allowed them to enter diabetes self-care data including blood glucose values, carbohydrate intake, and medications into mobile phones and receive automated, real-time educational, behavioral, and motivational messages related to entered data. The intervention also included a web portal consisting of a secure messaging center for patient and provider communication, personal health record, a learning library, and logbook to review entered data	The mobile phone-based intervention significantly improved HA1C compared to the usual care group. No differences were observed between groups for diabetes distress, depression, diabetes symptoms, blood pressure, or lipid levels
Song <i>et al</i> <sup>[53]</sup>	Internet-based DSMP	Evaluation of the efficacy of an internet-based diabetes self-management education program for newly diagnosed patients with type 2 diabetes as an alternative to group lectures	Participants in the intervention group participated in an internet-based diabetes self-management program and control group participants attended three hours of group lectures provided by healthcare professionals specializing in diabetes care	HA1C and diabetes care knowledge improved significantly in the intervention group at six weeks and diabetes care behaviors improved significantly at six weeks and three months. Diabetes

Tang <i>et al</i> <sup>[20]</sup>	Internet-based system	Evaluation of an online disease management system supporting patients with uncontrolled type 2 diabetes	Multicomponent intervention that included: wirelessly uploaded home glucometer readings with graphical feedback; patient-specific diabetes summary status report; nutrition and exercise logs; insulin record; online messaging with healthcare providers; self-management advice and medication management; and personalized text and video educational messages	care knowledge and diabetes care behaviors improved significantly in the control group at six weeks, but HA1C did not significantly change at six weeks or three months Participants in the intervention group had significantly reduced HA1C levels at 6 mo compared to a usual care group. At 12 mo, the differences were not significant
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SMBG: Self-monitored blood glucose; CASM: Computer-assisted self-management; CAPS: Computer-assisted self-management plus diabetes distress specific problem-solving; DSMP: Diabetes self-management program; HA1C: Hemoglobin A1C.

the study, 22 were randomized to the cell phone group and 18 to the email group; however, only 18 of the cell phone group and 11 in the email group actually used the system. Participants in the cell phone group requested more reminders and submitted more blood glucose values than those in the email group, but over time both groups significantly decreased the number of requested reminders and submitted blood glucose values<sup>[10]</sup>.

In another study, researchers developed a mobile phone application in conjunction with 12 people living with type 2 diabetes to assist with self-management<sup>[11]</sup>. Participants participated in focus groups and feasibility testing during development of the application. Qualitative interviews were conducted at study conclusion. The application included blood glucose monitoring, step counter, software for recording food habits, and feedback based on personal goals established prior to application use. Results of the study were positive. The majority of participants utilized the blood glucose sensor system one or more times per day and had a slight decrease in average blood glucose over the study period. As a group, participants had a reduced intake of carbohydrate-rich foods by the end of the study compared with the beginning of the study. Some participants found daily entry of consumed foods to be a tedious task. The step counter automatically transferred number of steps to the mobile phone once per day. Overall, participants increased their number of daily steps from study beginning to end. Participants especially liked the tips and feedback related to personal goals<sup>[11]</sup>.

A study designed to improve glycemic control without hypoglycemia in elderly people living with type 2 diabetes utilized mobile phones for the intervention<sup>[12]</sup>. Participants received a glucometer that downloaded to a hospital-based server and based on the data, patient-specific messages were generated and sent to their mobile phone. Text messages included instructions about changes to medications based on blood glucose values and reminders to check blood glucose as instructed. The intervention group had significantly lower hemoglobin A1C (HA1C) values compared to two control groups at

six months follow-up. Participants in the intervention group did have higher rates of hypoglycemia than participants in the two control conditions, but the difference was not statistically significant<sup>[12]</sup>.

Support for diabetes management has been provided through text messaging using mobile phones. A sample of 18 African American people living with type 2 diabetes completed a 4 wk text message diabetes program<sup>[13]</sup>. Participants were required to receive a daily medication reminder, question about medication adherence, question about foot care, and appointment reminders for diabetes-related visits. Participants could also receive additional diabetes management text reminders if desired. A certified diabetes educator (CDE) phoned participants weekly to obtain feedback on the experience and make adjustments to the personalized text message. The CDE did not provide any education, counselling, or clinical support for participants. Qualitative interviews revealed that the text message program reinforced the importance of self-management, increased awareness of diabetes, and improved feelings of control over diabetes<sup>[13]</sup>.

A mobile diabetes intervention study examined the effect of mobile phones and patient and provider portals for individualized patient treatment and communication on HA1C levels<sup>[14]</sup>. Participants with type 2 diabetes enrolled in the one year study and utilized a patient-coaching system consisting of a mobile diabetes management software application that allowed them to enter diabetes self-care data including blood glucose values, carbohydrate intake, and medications. After entering this data into mobile phones, participants received automated, real-time educational, behavioral, and motivational messages related to entered data. The intervention also included a web portal consisting of a secure messaging center for patient and provider communication, personal health record, a learning library, and logbook to review entered data. Researchers found a statistically significant improvement in HA1C levels in the intervention group compared to a usual care control group. The study did not evaluate how the mobile intervention affected behavior leading to

blood glucose changes. How the intervention affected medication adherence, physical activity, quantity and quality of patient-provider communication, and treatment intensification are important variables which should be considered in future studies<sup>[14]</sup>.

Of the six mobile phone intervention studies, three were qualitative and three were randomized controlled trials. Participants in the qualitative studies generally reported positive outcomes from using the mobile phone intervention. Participants appreciate the personalized feedback and education received from the intervention<sup>[11]</sup>. Participants in randomized controlled trials using a mobile phone intervention noted improvements in HA1C levels<sup>[12,14]</sup>. Overall, mobile phone interventions had small sample sizes making generalization of study findings difficult.

## INTERNET-BASED

Internet diabetes interventions provide opportunities to offer diabetes education, support, and motivation for self-management behaviors<sup>[2]</sup>. Web-based learning provides easy access without time or location restrictions and allows users to work at their own pace<sup>[3]</sup>.

A randomized controlled trial evaluated the effects of web-based diabetes education on HA1C levels and health check attendance<sup>[15]</sup>. Participants in both the experimental and control groups had completed basic diabetes education prior to this study. After six months of individualized patient education delivered over the web, the experimental group had significant decreases in HA1C and significantly higher health check attendance rates compared to the control group who received education from a diabetes nurse in a polyclinic setting<sup>[15]</sup>. No information was provided regarding amount of time participants spent accessing diabetes education either over the web or in the polyclinic.

A second randomized controlled trial aimed at reducing distress and enhancing effective management of type 2 diabetes compared three interventions to reduce diabetes distress and improve self-management<sup>[16]</sup>. The study enrolled 392 participants who were randomly assigned to computer-assisted self-management, computer-assisted self-management plus diabetes distress-specific problem-solving, or a computer-administrated minimal support intervention. Computer-assisted self-management included a web-based diabetes self-management improvement program that allows patients to select goals for medication adherence, diet, or exercise and monitor those goals. Participants in this group also had access to a forum to ask questions of diabetes experts and received phone calls from an interventionist to monitor progress and problems. The second group received this same computer-assisted self-management plus problem-solving therapy specifically for diabetes distress. The third intervention group received a computer-delivered health risk appraisal and diabetes information regarding healthy

living, diet, and physical activity. Significant decreases in diabetes distress, emotional burden, and regimen distress occurred in all three groups with no significant between-group differences. The study did not include a usual care control group so the effect of attention alone could not be measured<sup>[16]</sup>.

Similarly, a three-arm randomized controlled trial compared computer-assisted diabetes self-management, computer-assisted diabetes self-management plus human support, and enhanced usual care<sup>[2]</sup>. Participants in the computer-assisted diabetes self-management program (DSMP) selected achievable goals in the areas of medication adherence, physical activity, and food choices. They were able to view displays of their biophysical data, record progress toward goals, participate in a moderated forum, and view diabetes self-management information. Participants in this group also received periodic motivational calls. The computer-assisted plus human support group received the same computer intervention and received follow-up calls from an interventionist and opportunities to attend group educational sessions. The internet interventions significantly improved health behaviors including eating habits and adherence to medications compared to usual care over the 12 mo study period. All three conditions moderately improved self-efficacy, problem-solving, and HA1C<sup>[2]</sup>.

A six month randomized trial evaluated the effect of an internet-based DSMP on HA1C, diabetes symptoms, exercise, self-efficacy, and patient activation<sup>[17]</sup>. Participants were randomized to the intervention, intervention plus email reinforcement, or usual care. The internet-based DSMP consisted of six weekly sessions that participants could view asynchronously anytime during the week. The site also contained a learning center where participants could respond to a posed question and develop an action plan for dealing with diabetes-related problems. A discussion center included interactive threaded discussion boards viewable by all participants where comments, questions, and discussions could be posted. Lastly, a help section was included that allowed participants to email program administrators. The study had a large sample size with 732 completing the six months study and 645 completing the six months completion questionnaire. Following the 18 mo reinforcement period, 528 participants completed questionnaires. At six months, HA1C, self-efficacy, and patient activation were significantly improved for intervention group participants compared to usual care participants. The subgroup with a pre-study HA1C greater than seven demonstrated stronger improvement in HA1C. No significant changes were noted for diabetes symptoms and exercise. Reinforcement did not affect study outcomes. Those in the intervention plus email reinforcement had no significant improvements compared to the intervention group. Researchers recommend follow-up to determine if the type of reinforcement was not beneficial or if it was not properly utilized<sup>[17]</sup>.

A randomized controlled trial was conducted to

evaluate the effect of a web-based comprehensive information system on blood glucose control<sup>[18]</sup>. The system was available using a computer or cellular phone. The system provided real-time information about diet, dining out, hypoglycemia, sick day management, stress management, and diabetes management. HA1C and postprandial blood glucose were levels were significantly decreased in the intervention group, but not the control group after six months. There was a significant relationship between the HA1C change and frequency of website access with greater decreases in HA1C associated with higher website usage. The most frequently accessed information using cellular phones was the dining out section which may have contributed to improved postprandial glucose levels. Participants accessed the website more often using the cellular phone than the computer<sup>[18]</sup>.

A randomized controlled trial found that electronic presentation of diabetes education was as effective as traditional face-to-face education in newly diagnosed patients with type 2 diabetes<sup>[19]</sup>. A total of 68 participants were randomly assigned to one of three educational models. The control group received structured diabetes education in a traditional classroom setting. This group also had direct verbal communication with health care providers. The second group had access to electronic educational materials and tools and used asynchronous communication through email for interactions with providers. The third group had access to electronic education materials and tools, used asynchronous and synchronous communication with providers and patients, and used an electronic blood glucose journal and other functions. All three groups had similar improvements in diabetes knowledge, self-efficacy, diabetes self-care activities, and HA1C with no significant between-group differences<sup>[19]</sup>.

A quasi-experimental design study was conducted to compare a web-based diabetes education program with a traditional classroom diabetes education program for newly diagnosed adults with type 2 diabetes<sup>[3]</sup>. The web-based program included six education modules covering diabetes basics, dietary management, exercise, medications, stress management, and foot care. The website also included a password-protected space where participants could enter glucose levels and see a display of those levels, calculate caloric content of meals consumed, record activities, and measure daily stress levels. Participants in the control group attended one hour lectures every week for three consecutive weeks in a group setting consisting of 30 to 40 participants that were taught by a diabetes care specialist nurse, dietician, and physician. Diabetes knowledge, care behaviors, and glycemic control were compared for the intervention and control groups at baseline, six weeks, and three months. Diabetes care knowledge significantly increased in both intervention and control groups from baseline to six weeks, but not from six weeks to three months. Diabetes care behaviors

significantly increased in both groups from baseline to six weeks and also significantly increased from six weeks to three months in the intervention group. HA1C levels for the intervention group significantly decreased from baseline to six weeks, but not from six weeks to three months. No differences in HA1C were found in the control group. Limitations of this study include the small sample size (31 participants) and the lack of random group assignment. Participants in the intervention group were required to have the ability to use the internet which prevented random assignment. The improvement in diabetes care behaviors and HA1C in the intervention group offers promise for using web-based diabetes education as a substitute for group education<sup>[3]</sup>.

A randomized controlled trial evaluated an online diabetes management system for patients with uncontrolled type 2 diabetes<sup>[20]</sup>. A usual care control group was compared to an intervention group that utilized an online disease management program that included wireless uploading of glucose readings, individualized diabetes summary status reports, nutrition and exercise logs, insulin records, online messaging with the health care team, advice and medication management from a nurse care manager and dietician, and personalized educational information. Participants in the intervention group had significantly lower HA1C levels at 6 mo compared to the control group, but at 12 mo, the difference was no longer significant. As in other studies, participants who utilized the online system more often achieved greater benefits<sup>[20]</sup>.

Internet interventions include education, goal-setting, tracking of behaviors, patient feedback and support. Of the eight internet studies reviewed, seven were randomized controlled trials and the remaining study had a quasi-experimental design. All studies that measured changes in HA1C levels noted improvements and all improvements were significant with one exception<sup>[2]</sup>. In two of the studies, short-term improvements were noted in HA1C, but not at the second, long-term follow-up<sup>[3,20]</sup>. Several studies noted improvements in outcomes in both intervention and control groups<sup>[2,3,16,19]</sup>.

## CONCLUSION

Previous reviews found mixed results with some noting significant improvements in HA1C and self-management behaviors<sup>[8]</sup>. This review found mainly positive results though some interventions had no effect or only short term improvements. It is important to note that greater usage of technological interventions, both mobile and internet-based, was associated with greater improvements in outcomes<sup>[18,20]</sup>. One of the reviewed studies included a web-based intervention that could be accessed using the computer or mobile phone. Researchers found that participants in the mobile phone group accessed the site more often than those using the computer<sup>[18]</sup>. Mobile phone interventions are an important source of diabetes self-management

to pursue as their convenience may increase access of information and support for people living with diabetes.

Due to time constraints of both patients and healthcare providers, web-based education and monitoring may be beneficial and can be used to complement healthcare provider visits<sup>[15]</sup>. Increased access, whether in-person or electronic, to diabetes education and healthcare providers can improve diabetes knowledge and self-efficacy<sup>[19]</sup>. The increased use of diabetes-related mobile applications indicates that people living with diabetes are interested in using these methods to improve self-management and diabetes outcomes. The use of applications to provide education and real-time feedback needs to be developed<sup>[5]</sup>.

## RECOMMENDATIONS

While technology can be effective for promoting diabetes education, support, and self-management, patients report a need for personal contact with health care providers in addition to technology<sup>[9,13]</sup>. In the study by Nundy *et al*<sup>[13]</sup>, automated text messages were sent, but participants stated they preferred to think of them as coming from the certified diabetes educator (CDE) who enrolled them in the study. They also appreciated the weekly calls from the CDE to obtain feedback on the experience and make adjustments to text messaging as needed. Some participants felt the text messaging intervention would not be effective for them without a person to monitor and provide clinical support<sup>[13]</sup>. A website that provides diabetes education, monitoring, and support through communication with a healthcare provider may be most effective<sup>[15]</sup>. Web-based interventions can be used in conjunction with healthcare provider education and support and as a follow-up to healthcare provider interventions<sup>[21]</sup>.

Researchers and healthcare providers should include participants in the development of technological interventions and in the decision of which technology to use<sup>[9]</sup>. Patient needs must be explored to determine the best method for individual needs realizing that not all patients will be amenable to technological interventions<sup>[21]</sup>. A previous review of mobile diabetes applications found that current applications are lacking personalized education and decision support features are not being included. Additionally, inclusion of peer support features through mobile applications are largely underused and could be beneficial for people living with diabetes<sup>[22]</sup>.

## IMPLICATIONS FOR PRACTICE

Healthcare providers should actively select and adapt technological self-management methods to extend the reach of diabetes self-management to patient's communities and homes, provide for individualized care, and provide just-in-time information. People living with diabetes who have limited access to care due to lack of transportation, physical restrictions, or other limitations

could benefit from technological interventions that bring care to them<sup>[21]</sup>. Additionally, with limited primary care resources, technology can provide cost-effective ongoing diabetes self-management education and support<sup>[2]</sup>.

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