# Support for Diabetes Using Technology: A Pilot Study to Improve Self-Management

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*Technology may assist people living with type 2 diabetes with self-management. A pilot study that used Apple® iPad® technology to support diabetes self-management is described.*

According to the American Diabetes Association (ADA, 2013a), 25.8 million people in the United States currently are living with diabetes. Approximately 90%-95% of these have type 2 diabetes (T2DM). If not managed properly, diabetes leads to multiple complications, including heart disease, stroke, high blood pressure, kidney disease, blindness, and limb amputation. Management of diabetes requires participation in a multifaceted program. The complex nature of diabetes treatment plans makes it difficult for people living with diabetes to understand and maintain daily self-management (Sevick et al., 2008). Technology may assist with processing the complexities of a self-management plan by providing education and visual feedback of self-management behaviors.

## Review of Literature

People living with diabetes are encouraged to follow a healthy diet, monitor blood glucose, exercise, take prescribed medications, and monitor for diabetes-related complications by daily inspecting skin and feet and obtaining an annual eye examination (ADA, 2013b). Self-care management interventions improve glycemic control in people living with T2DM, leading to greater well-being and decreased complications (Minet, Moller, Vach, Wagner, & Henriksen, 2010; Renders et al., 2009). Prior to study onset, a literature review was conducted for the years 2007-2012 using PubMed, CINAHL, and PsycINFO databases. Search terms included *diabetes self-management*, *diabetes self-management behaviors*, *diabetes and self-efficacy*, and *diabetes and technology*.

Research indicates self-efficacy is linked closely to diabetes self-management, with higher levels of self-efficacy being related to increased participation in diabetes self-management behaviors (King et al., 2010; Lanting et al., 2008; O'Hea et al., 2009). Methods to promote self-efficacy in persons with diabetes have the potential to improve diabetes self-management, thereby improving overall disease control. Technology is being used increasingly to assist people living with diabetes with self-management. New technological advances can improve self-management by encouraging patients to participate in practices and routines related to their illness and providing educational and motivational support for day-to-day diabetes management.

Technological interventions offer promise for enhancing self-efficacy and support for diabetes self-management. One study evaluated three different methods of diabetes education delivery, including two different web interactive methods and a traditional face-to-face education (Pacaud, Kelley, Downey, & Chiasson, 2012). Improvements in diabetes knowledge, self-efficacy, and self-management were noted for all three methods. Significant correlations were found between higher website usage and higher diabetes knowledge, self-efficacy scores, and metabolic control. Researchers concluded diabetes education delivered electronically can be as effective as the traditional face-to-face delivery method and may offer options for meeting the increasing demands for diabetes self-management education.

Another study evaluated the effect of a text message-based diabetes program on diabetes management

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(Nundy, Dick, Solomon, & Peek, 2013). Participants received daily text messages about taking medications, weekly reminders about foot care, and appointment reminders for diabetes-related visits. They also could request additional messages related to diabetes care, such as reminders about glucose monitoring. The intervention improved self-efficacy for self-management by providing feedback on self-management and relating symptoms to self-management behaviors. Qualitatively, participants reported the text messaging intervention increased self-awareness and control, provided reinforcement and feedback, increased realization of the significance of diabetes, and provided caring and support.

An online diabetes self-management program was evaluated by Lorig and co-authors (2010). Participants accessed a website for educational sessions and weekly learning activities. They also formulated an action plan for each week. Participants in the intervention group had significant improvements in self-efficacy for diabetes self-management compared to the usual care control group.

Research has been conducted using handheld devices to promote diabetes self-management. A randomized controlled trial of 151 participants tested the use of personal digital assistants (PDA) for improving diabetes regimen adherence (Sevick et al., 2008). Researchers found the PDA self-monitoring enhanced accuracy of estimated caloric intake and expenditure, enhanced vigilance to the dietary regimen, allowed problem-solving for glucose control issues by examining dietary intake and glucose values, and allowed positive reinforcement and goal revision as needed.

A qualitative study used a mobile phone and web-based collaborative care intervention for patients with T2DM (Lyles et al., 2011). Smartphones and other technology to support diabetes self-management were provided to study participants. Most participants appreciated email communications with the nurse and found it easy to upload glucose information from meters. However, most participants found the smartphones to be frustrating. These participants had not used a smartphone previously and had difficulty with basic operation of the phone. Participants and researchers recommended using the technology with devices already familiar to patients. Although participants found the smartphones frustrating, most believed the program increased awareness of their health and helped them to be more focused and accountable for self-managing diabetes.

An experimental study was conducted to evaluate the effects of interactive multimedia on participants' diabetes knowledge, ability to control blood glucose, and self-care (Huang, Chen, & Yeh, 2009). Following the 3-month intervention, members of the experimental group had significantly higher diabetes knowledge levels than those in the control group who received a routine education program. Researchers found no significant differences between groups for glycosylated hemoglobin (A1C) values or self-care behaviors. A1C improved for the experimental group, but not to a level of significance. Additionally, the experimental group showed improvement in all self-care behaviors except exercise for the study period; however, improvements again did not reach a level of statistical significance. Participants in the experimental group were satisfied with the diabetes interactive multimedia, indicating this may be an acceptable method for diabetes self-management education.

Diabetes self-management interventions also are being delivered using the Internet. An Internet computer-assisted diabetes self-management intervention utilized goal-setting for medication adherence, physical activity, and food choices (Glasgow et al., 2012). Participants recorded progress toward goals and created action plans to address barriers to goal achievement. Health behaviors improved significantly for experimental group participants compared to control group participants. Researchers noted greatest improvements at 4 months with small effects at 12 months.

Tang and colleagues (2013) conducted a multicomponent randomized controlled trial to evaluate an online disease management system to support people living with T2DM. The intervention included wireless uploading of glucose readings with graphical feedback, nutrition and exercise logs, online messaging with the health care team, personalized text, and video education. At 6 months, A1C values for intervention group participants were significantly lower compared to control group participants. The difference was not significant at 12 months, however, possibly due to significant improvements in A1C among control group participants at this time. Intervention group participants also had significantly better low-density lipoprotein cholesterol values at 12 months, but no differences were seen for blood pressure or weight.

Self-management behavior tracking, as well as improved access to diabetes education and health care providers, can increase knowledge, self-efficacy, and participation in self-management behaviors, and ultimately may improve diabetes outcomes (Pacaud et al., 2012). Health care professionals should develop and implement self-management support technology programs to meet the need to deliver individualized, cost-effective care that can reach into communities and homes (Fisher & Dickinson, 2011). While literature supports the use of technology to meet the needs of people living with diabetes, more research is needed to determine which types of technological interventions are most beneficial. Technology should be evaluated for motivation for diabetes self-management, user satisfaction, and diabetes outcomes.

## Purpose

The purpose of this pilot study was to determine if the use of applications on Apple® iPad® technology that support diabetes self-management will increase self-efficacy for self-management, increase participation in self-management behaviors, and improve diabetes outcomes in persons with T2DM in an employer-sponsored diabetes self-management program. Specific aims for the project included the following:

- Increase self-efficacy for diabetes self-management.
- Increase participation in diabetes self-management behaviors, including monitoring blood glucose, taking medications, exercising, and following a recommended eating plan.
- Improve diabetes control (A1C).

## Theoretical Framework

The study was guided by Self-Determination Theory, a general theory of human motivation which suggests people have three innate psychological needs: autonomy, competence, and relatedness to others (Deci & Ryan, 2002). Autonomy involves self-regulation of behaviors through experience and reflective self-endorsement. Competence refers to a person's confidence in the ability to self-manage and is similar to the self-efficacy concept. Relatedness involves feeling meaningfully connected to others. Feeling a partnership with health care providers increases desire to participate in self-management behaviors. Self-Determination Theory indicates support for these three needs will enhance both mental and physical health. People are more likely to adopt healthy behaviors when these basic needs are supported. This intervention can increase autonomy by allowing self-management behaviors to be tracked and reviewed. This permits reflection on self-management through visual representation of how day-to-day activities affect outcomes such as blood glucose. The use of technology to track self-management can increase competence when people living with diabetes see positive results based on behaviors. Relatedness can be accomplished through feedback obtained from health care providers based on documented self-management behaviors.

## Methods

### Design and Sample

This pilot study used a two-group, crossover, repeated-measures design. Participants were recruited from the employee health group of a diabetes and nutrition center at a local medical center in an urban area of the Southeast. Representatives from the employee health program posted study informational flyers at the center. An informational email blast describing the study and providing researcher contact information was sent by a representative to all employees enrolled in the health program. Interested persons were referred to the primary investigator for questions about study enrollment if they met the inclusion criteria. Inclusion criteria were people living with T2DM, age 19 or older, and able to read and write English. The goal was to enroll 20 employees in the pilot study. Approximately 60 people contacted the primary investigator about study participation; 17 met inclusion criteria and agreed to participate. The primary reason given by potential participants for not enrolling in the study was a lack of time.

### Procedures

The study proposal was reviewed and approved by the institutional review boards from the university leading the study and the participating hospital. The primary investigator met with potential participants at the diabetes and nutrition center. Study details were explained and a written informed consent document was provided. Potential participants were given the opportunity to ask questions. Those who were interested in participating in the study signed the consent document and were given a copy. Following informed consent, participants completed pre-intervention demographic, self-efficacy, and diabetes self-management questionnaires. Baseline A1C values were collected by diabetes and nutrition center staff and documented by researchers.

Participants were assigned randomly either to the intervention (iPad) or control (journal) group. The primary investigator distributed the Apple iPad devices and provided instructions on using the diabetes self-management application to log behaviors. Participants also were instructed how to email logs to the primary investigator once per week using a single GMail account established for the study. The control group participants were given instructions on how to log diabetes self-management activities in the provided journal. Participants in both groups were asked to log diabetes self-management behaviors in the following categories: monitoring blood glucose, following a recommended eating plan, exercising, and taking medications on a daily basis. Contact information for the primary investigator was provided in case participants required assistance or had questions during the study period. The initial meetings, which lasted approximately 1 hour, were conducted either in groups or individually according to participant preference.

Researchers met with participants from both intervention and control groups 3 months following the initial meeting to complete mid-intervention assessments. At this time, participants in the iPad group were given a paper journal to log diabetes self-management activities for the next 3 months. Participants in the paper journal group were given an iPad to document diabetes self-management behaviors for the next 3 months. A final assessment was completed after this 3-month study period. A diabetes educator from the diabetes and nutrition center was available throughout the study period to answer participant questions related to their medical treatment programs.

### Measures

Demographic information including age, sex, race, length of time diagnosed with diabetes, and highest level of education was obtained prior to the study. Pre-intervention, mid-intervention, and post-intervention measures of self-efficacy and diabetes self-management were obtained. The Diabetes

Management Self-Efficacy Scale (DMSES) (van der Bijl, Poelgeest-Eeltink, & Shortridge-Baggett, 1999) was used to measure self-efficacy. The 20-item instrument includes questions about self-care activities people living with T2DM must perform to manage the disease, including eating a heart healthy diet, participating in physical activity, monitoring blood glucose, taking medications, and monitoring for complications. The 10-point Likert scale assessed patients' confidence in their ability to manage their diabetes, with higher scores indicating higher levels of self-efficacy. Internal consistency of the total scale measured by Cronbach's alpha ranged from 0.81 to 0.92 in previous studies (Coffman, 2008; Hunt et al., 2012; van der Bijl et al., 1999).

Participation in diabetes self-management behaviors was measured using the Summary of Diabetes Self-Care Activities-Revised (SDSCA) questionnaire (Toobert, Hampson, & Glasgow, 2000). The instrument contains 11 items to evaluate the frequency with which participants engage in self-management behaviors, including diet, exercise, medication use, blood glucose testing, and foot care. Respondents indicate the frequency with which they participated in each self-management behavior in the last 7 days. Mean number of days is calculated for each category of self-management behaviors, with higher scores indicating more frequent participation in self-management behaviors. Overall internal consistency as measured by Cronbach's alpha ranged from 0.65 to 0.84 in previous studies (Eigenmann, Colagiuri, Skinner, & Trevena, 2009; Hunt et al., 2012).

An iPad application (Diabetes Buddy®) was loaded on each device to track self-management behaviors. Diabetes Buddy was chosen because it allows tracking of the recommended diabetes self-management behaviors of glucose monitoring, eating a healthy diet, exercising, and using medication. The application also allows emailing of data from within the application as well as unlimited logging of behaviors. Participants logged behaviors each day and emailed a report of activities each week to the primary investigator. Control group participants logged the same behaviors using a paper journal.

### Data Analysis

Descriptive statistics were used to analyze demographic data and A1C values. Pre-test and post-test measurements of self-efficacy and diabetes self-management behaviors were analyzed using a mixed model analysis of variance with the group (monitoring method) as the between-subjects factor, and self-efficacy and diabetes self-management behaviors as the repeated factors. A repeated measures analysis also was used to determine changes in self-management behaviors over time.

## Results

### Demographic Characteristics

During the first phase of the study, 3 of the 17 participants withdrew due to time constraints or family issues; the final sample was 14 participants (see Table 1 for demographic characteristics). Ten participants (59%) were female and 11 (65%) were over age 50. Thirteen (77%) of the participants had been diagnosed with T2DM less than 10 years.

### Hemoglobin A1C

The sample for this pilot study had good glycemic control at baseline with an average A1C of 6.59%. No additional A1C values were available during the study period.

### Self-Efficacy

The mean and standard deviation (*SD*) self-efficacy score for the entire sample as measured by the DMSES was high at 8.55 (+/- 0.89). This self-efficacy mean score falls within the "certain can do" for the DMSES. The group using iPads in the first arm of the study had significantly higher baseline self-efficacy scores than the second group with means (*SD*) at 9.1 (+/- 0.76) and 8.1 (+/- 0.43), which continued throughout the study. Self-efficacy scores for the first iPad group ($n$=6) remained relatively the same from baseline to mid-intervention and post-intervention (9.1, 9, and 9.2). Self-efficacy scores for the second iPad group ($n$=8) decreased slightly from baseline to mid-intervention after logging using the journal and increased after using the iPads, but not to a level of significance (8.1, 7.9, and 8.7). Analysis of $t$-tests revealed no statistically significant change in either group with iPad use, indicating the intervention did not impact self-efficacy in this sample.

### Diabetes Self-Management

The mean diabetes self-management score for the sample as measured by the SDSCA was 5.1 (+/- 0.89) at baseline. For the group using iPads first, SDSCA scores remained the same, but decreased slightly after using the journals to log behaviors (5.4, 5.3, and 5). For the group using iPads for the second half of the study, SDSCA scores decreased after journal use, but significantly increased at post-intervention after using the iPads (4.8, 4.6, and 5.2). Analysis of $t$-tests revealed no significant differences between groups.

### Activity Logs

A comparison of self-management behavior activity logs between iPad use and journal use revealed mixed results. Some participants logged more self-management behaviors when they used the iPad and others logged more activities using the journal. This may indicate the process of tracking self-management behaviors may be more important than the method used to track behaviors. Personal preferences must be considered.

## Discussion

Results revealed no difference in self-efficacy scores between the iPad and journal study groups; however, self-efficacy scores were very high at baseline, making it difficult to identify improvement. A larger, more varied sample is needed for additional evaluation. Additionally, the average A1C of 6.5% for the sample

**TABLE 1.**
**Sample Demographics**

| Characteristic | *n* | % |
|---|---|---|
| **Sex** | | |
| Male | 7 | 41.2 |
| Female | 10 | 58.8 |
| **Age** | | |
| 19-50 | 6 | 35.3 |
| 51 and older | 11 | 64.7 |
| **Race** | | |
| African American | 3 | 17.7 |
| Caucasian | 13 | 76.5 |
| Other | 1 | 6 |
| **Educational Level** | | |
| Less than high school graduate | 1 | 6 |
| High school graduate and some college | 11 | 64.7 |
| College graduate or professional degree | 5 | 29.3 |
| **Number of Years Diagnosed with Diabetes** | | |
| 10 years or less | 13 | 76.5 |
| 11 years of more | 4 | 23.5 |

indicated good glycemic control. These findings support previous research indicating higher levels of self-efficacy are linked with improved glycemic control. Self-efficacy areas that were scored lowest by participants involved following a healthy eating plan. This also supported previous research indicating people living with diabetes struggle with dietary self-management (Booth, Lowis, Dean, Hunter, & McKinley, 2013; Franks et al., 2012; Song & Kim, 2009).

Participant scores on the SDSCA remained the same in the first iPad group and significantly increased in the second group after iPad use. The significant increase in the second group may indicate tracking of behaviors using the iPad application increases awareness of and need to participate in self-management. Both groups had decreases in SDSCA scores at midpoint. Perhaps documenting behaviors led to participants' realization they were not performing self-management as often as they thought. Of the SDSCA categories, taking medications had the highest score while exercise had the lowest. Similar results were found in previous studies (Al-Khawaldeh, Al-Hassan, & Froelicher, 2012; Hunt et al., 2012; Song & Kim, 2009).

A1C values were collected by diabetes and nutrition center staff and reported to the primary researcher. Because the majority of participants were below 7%, staff did not recommend obtaining another A1C for 6 months. At the 6-month point, most participants did not have another A1C drawn primarily because the diabetes and nutrition center was in the process of relocating and the primary researcher had to meet participants at other locations for the post-intervention data collection.

Qualitatively, participants offered mostly positive comments about using the iPad application to track self-management behaviors. Participants discussed how the application had helped them keep track of blood glucose levels, food intake, and exercise. One participant liked the carbohydrate counter and indicated she had not known how to track carbohydrates prior to using the application. Participants found the summary of activities helpful and liked having all the self-management information available at a glance. For some participants, seeing all the information in one place enabled them to link self-management activities with glucose control. For example, a participant stated he did not realize until he began tracking his exercise that if he exercised more, his glucose was lower and he did not have to use as much insulin. One participant said tracking made him realize he was not doing enough to manage his diabetes even though he thought he was.

## Nursing Implications

The complexity of diabetes management makes the use of technology important to improving outcomes for patients with diabetes. Technological advances offer promise for promoting diabetes self-management (Liang et al., 2011; Lyles et al., 2011; Pal et al., 2013). Providing technology to promote tracking of diabetes self-management encourages patient autonomy. Patients can visualize progress toward goals using diabetes applications, which will promote competence. Supporting patients in self-management through technology may improve diabetes outcomes. Effective self-management contributes to blood glucose control, lowered blood pressure and cholesterol, avoidance of complications, and improved quality of life (Funnell et al., 2007; Jones et al., 2003; Sousa, Zauszniewski, Musil, Lea, & Davis, 2005). In contrast, patients who do not participate in daily self-management activities have an increased risk for developing diabetes-related complications, including stroke, heart disease, kidney disease, limb amputation, and blindness (American Association Diabetes Educators, 2006).

As identified in this study as well as previous research, diet and exercise are two areas with which people living with diabetes struggle and could benefit from support. An Internet-based intervention produced significant improvements in healthy eating and physical activity for a group of people living with T2DM (Glasgow et al., 2012). Nurses can provide education in these areas and use available technological resources to help patients access ongoing education and support in these areas.

A growing number of people have access to smartphone and Internet technology (Brenner, 2013; Duggan & Smith, 2013). As technology and devices become more accessible, options for use in chronic disease management will increase. Technology can be used to supplement health care provider education and support when resources, including time, are limited. Technology that is accessible at the time a patient needs it offers continuous support and tools for managing multiple self-care behaviors (Glasgow et al., 2012). Nurses should be knowledgeable about various technological advances and assist patients to identify technology that can be used to facilitate diabetes self-management.

### Limitations

This pilot study included a small convenience sample. Participants had good glycemic control and high self-efficacy scores at baseline, which may have limited the effectiveness of the intervention. An additional limitation was the use of self-report measures. The study required participants to log self-management activities each day. Due to time constraints or other issues, participants may have performed self-management activities but did not log them using the iPad application or journal. The logs may not represent accurately the number of self-management activities participants completed each day. Finally, the food entry section of the iPad application was reported to be tedious to use. Participants had to follow multiple steps to enter a consumed food and locating foods was difficult. Every participant qualitatively listed the food entry as problematic on the iPad application evaluation.

### Recommendations for Future Research

Findings from this pilot study will be used as preliminary data to guide a larger study to evaluate the effect of technology to support diabetes self-management for people living with T2DM. Expanded recruitment sites will be used to obtain a heterogeneous sample. Future directions include exploration of providing diabetes self-management education and social support using smartphone applications. Provision of both general and personalized health education through technological devices is lacking (Chomutare, Fernandez-Luque, Arsand, & Hartvigsen, 2011). Research should focus on integration of diabetes management education and health care provider/peer support for people with diabetes using technology. Current studies indicate technology can have a positive impact on diabetes self-management. The potential for technological advances as adjuncts to clinical care should be explored. Future studies should identify which technologies are most effective for improving self-management and diabetes outcomes. Additionally, other potential uses of technology for self-management should be explored.

## Conclusion

Self-management requires people living with diabetes to understand the multifaceted treatment plan, and modify and maintain daily behaviors. Maintaining daily self-management is necessary, but challenging. As technology advances, health care providers need to reinvent approaches to educating and assisting patients to self-manage T2DM. Research is needed to evaluate the most effective forms of technology for promoting diabetes self-management. MSN


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