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REVIEW ARTICLE

A Review of Web-Assisted Interventions for Diabetes Management: Maximizing the Potential for Improving Health Outcomes

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Abstract

Current endeavors in diabetes care focus on helping patients and providers deal successfully with the complexities of the disease by improving the system of care, expanding the reach of interventions, and empowering patients to engage in self-care behaviors. Internet technologies that combine the broad reach of mass media with the interactive capabilities of interpersonal media provide a wide range of advantages over standard modes of delivery. The technical affordances of Web delivery enable individualization or tailoring, appropriately timed reinforcement of educational messages, social support, improved feedback, and increased engagement. In turn, these have been significantly correlated with improved health outcomes.

This article is a narrative review of Web-based interventions for managing type 2 diabetes published from 2000 to 2007 that utilize Web sites, Web portals, electronic medical records, videoconference, interactive voice response, and short messaging systems. The most effective systems link medical management and self-management. Patient satisfaction is highest when the Web-based system gives them the ability to track blood glucose, receive electronic reminders, schedule physician visits, email their health care team, and interact with other diabetic patients. However, comprehensive medical and self-management programs have not been implemented widely outside of systems funded by government agencies. The cost of developing and maintaining comprehensive systems continues to be a challenge and is seldom measured in efficacy studies. Lack of reimbursement for Web-based treatments is also a major barrier to implementation. These barriers must be overcome for widespread adoption and realization of subsequent cost savings.

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Abbreviations: (EMR) electronic medical records, (IVR) interactive voice response, (SMS) short messaging systems, (VA) Veterans Administration

Keywords: chronic care model, chronic disease, diabetes self-management, EMR, hemoglobin A1c, IVR, medical management, SMS, type 2 diabetes, videoconferencing, Web portal, Web site

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Introduction

The future of diabetes care lies in finding ways to help patients and providers deal successfully with the complexities of the disease by improving the system of care, expanding the reach of interventions, and empowering patients to engage in self-care behaviors.[1] Web-assisted diabetes management refers to interventions that involve the use of Internet technologies such as email, chat rooms, discussion groups, data uploads, electronic medical records, and short messaging systems (SMS) to enhance patient education, communication with providers, monitoring (e.g., blood glucose, diet, physical activity, blood pressure), goal setting, medication management, problem solving, and psychosocial adaptation. Web-assisted diabetes management can facilitate patient and physician roles to improve clinical outcomes.[2]

Internet technologies that marry the broad reach of mass media with the interactive capabilities of interpersonal media provide a wide range of advantages over standard modes. These include interactivity,[3,4] homophily or common experience,[5] social distance, and sense of privacy.[6] These technical affordances enable individualization or tailoring,[7–13] appropriately timed reinforcement of educational messages,[14,15] social support,[5,16–24] improved feedback between patient and provider,[14] and increased engagement.[25] In turn, these have been significantly correlated with improved health outcomes.[26,27] The United Kingdom Prospective Diabetes Study demonstrated that the risk for macrovascular and microvascular complications is reduced 14–37% with each percentage point decrease in hemoglobin A1c.[28]

Diabetes management/care supplemented or delivered through Web technologies has been shown to decrease morbidity and mortality in a number of studies.[4,29–32] Ultimately, these can lead to significant decreases in health care costs. Unfortunately, the tendency has been to design interventions around the technology rather than use the technology to meet core clinical or self-management outcomes. This article presents a narrative review of Web-based interventions for managing type 2 diabetes published from 2000 to 2007. Key issues affecting health outcomes, efficacy, design characteristics, application to diabetes management, and care are discussed. Finally, gaps in this area of research are described. The overall goal is to help shed light on how Web delivery contributes to improved health outcomes in diabetes care and how the use of Internet modalities can be maximized.

How Internet Technologies Have Been Used in Diabetes Treatment

A number of Internet and emerging Web technologies have been used to facilitate the delivery of diabetes care. These include Web sites, Web portals, electronic medical records (EMR), videoconference, interactive voice response (IVR), and SMS.

Web Site

Web sites are the most frequently used technology in diabetes care. Web sites are used to monitor, educate, provide feedback, and facilitate communication with medical staff. Patients have accessed Web sites via personal computers, messaging devices connected to plain old telephone system lines,[33,34] cell phones,[35] and handheld devices.[36] A number of Web sites focus on diabetes self-management,[33,34,37,38] weight management,[36,39,40] physical activity,[37,38,41,42] tailored physical activity,[13,38,43] diet,[13,38,44] blood glucose monitoring,[13,35] data upload of blood glucose values,[33,34,36,42] cardiovascular disease risk,[36,45–47] and blood pressure.[36,48]

Interactive Web site features increase knowledge, support engagement, increase self-efficacy, and facilitate behavior change through personalized feedback,[38,43] resource libraries,[42,45,46] tailored information,[42,49] asynchronous discussion boards,[42] synchronous chat,[42] email to or from medical staff,[38,42] and social support.[18,38,44,50–52] Outcomes of trials lasting 12–120 weeks using Web sites showed a 1.2–16.0% decrease in hemoglobin A1c with 0–43% attrition reported. This is consistent with the meta-analysis reported by Norris and colleagues in 2002.[15]

The Veterans Administration (VA)[34,36] and IDEATel Centers for Medicare and Medicaid Services demonstration projects are examples of comprehensive Web sites used for chronic disease management.[45,46, 52–55] The VA program contained coordinated medical and self-management components. It is widely accepted that a combination of medical and self-management maximizes outcomes.[56] However, Meigs and co-workers[57] achieved a 2.7% drop in hemoglobin A1c with medical management alone. The intervention utilized a Web-based decision support tool developed to improve evidence-based management of type 2 diabetes. This is important because it highlights the critical role of getting the right information to physicians to promote implementation of evidence- based guidelines.[57–61] Web-based communication can facilitate this process.

Web sites have also been used successfully to screen for diabetic retinopathy[62–64] and to monitor chronic wounds.[65,66]

Web Portal

Web portals serve as points of access to information on the Internet from varied sources and are organized and presented in a cohesive manner.[67] Web portals have been used in diabetes treatment to (a) allow access to electronic medical records, medication, and health history; (b) provide preventive health care reminders, educational materials, and self-management resources, and (c) facilitate data uploads.[45,46,68] In one study, patients rated the ability to log and track blood glucose levels over a 90-day period as one of the most useful features of a portal.[68] IDEATel used a Web portal for uploading and entry of clinical data.[45,46] The 52-week intervention involving a large sample of 1665 patients in a self-management intervention achieved a 5.2% drop in hemoglobin A1c with an attrition rate of 18.2%.

There is some indication that portals have greater appeal for men, although women tended to access portals more often.[68] While portals are very popular, focus groups have shown consistently that patients are unwilling to pay for these services as they see the Internet as "free."[68–71]

Electronic Medical Records

A number of studies have begun to look at how EMR's can be integrated with diabetes management. The patient's electronic medical record is the hub of the system. A feature common to most systems reviewed is the ability of patients and medical staff to enter data into the record.[68,72,73] The goal of these systems is to improve disease outcomes by linking home-based monitoring, self-management support tools, case management, clinical information, and decision support systems.[72,73] However, the technology must be integrated into a comprehensive disease management program for it to be effective. Use of the EMR alone to increase physicians' adherence to evidence-based practice guidelines is unlikely.[59,74]

A word of caution is in order. It is imperative that a feedback loop is included in any system that allows direct interface between home-based monitoring systems and the EMR. Clinicians need to be alerted when values exceed certain thresholds so that a rapid response is enabled and treatment regimens can be altered.[27,66,72–77]

Videoconferencing Systems

Videoconferencing involves the transmission of live video and audio between different locations. A growing body of data suggests that videoconferencing used in diabetes care may be more effective than voice-only-contact.[45,46] The home telemedicine unit used in the IDEATel project included capabilities for synchronous videoconferencing with nursing staff at 8–15 frames per second. Results showed that the use of videoconferencing mimicked face-to-face encounters and increased patient satisfaction.[66]

Interactive Voice Response Systems

Interactive voice response systems send patients recorded messages. Patients then respond by reporting clinical or other information using the telephone's touch-tone keypad, voice, or in-home messaging device.[78] This technology has been used successfully to decrease health care utilization costs for elderly diabetic patients in the VA system.[36] The intervention resulted in a 40% decrease in office and emergency room visits and a 30% drop in days hospitalized. Ironically, there was also a 16% increase in outpatient visits, which may have prevented more costly emergency room visits or in-patient hospitalization.[33]

Short Messaging Systems

Short messaging systems send short text messages to or from mobile phones. Several interventions used SMS as part of an Internet-based blood glucose monitoring system. Patients uploaded blood glucose or blood pressure data to a secure Internet server via cell phone, which were immediately posted to their EMR. Medical staff reviewed and transmitted recommendations back to the patient via SMS.[35,79]

One of the greatest challenges in diabetes management is maintenance of improved clinical outcomes. A 30-month study of a Web-based SMS showed that monitoring can reduce and maintain decreases in hemoglobin A1c. Levels were 7.7 ± 1.3 at baseline, 6.9 ± 1.1 at 15 months, and 6.7 ± 0.9 at 30 months.[80] The pervasiveness of cellular phones worldwide makes this type of system a very viable option. The caveat is having staff assigned to provide routine monitoring and feedback.[72,81]

Characteristics of Web-Assisted Interventions

The following section discusses common characteristics of Web-assisted interventions. Web-assisted medical management refers to interventions that use technology to facilitate diagnosis, monitoring, and treatment. Web-assisted self management interventions focus on patient self-management or health education.

Medical Management

Adherence to evidence-based guidelines improves clinical outcomes for diabetes,[56] hypertension,[82] and hyperlipidemia.[83] Systems that resulted in greater adherence to evidence-based guidelines included one or more of the following features: linking to electronic medical records,[35,48,52,66,77,80] computerized prompts for staff and/or patients,[84,85] reports, feedback, decision support,[57,72,73] emailed clinical recommendations,[59] and electronic scheduling.[57,66,85] Systems must be integrated seamlessly so that the staff perceive it as the way care is provided rather than an "extra" burden.[57]

Self-Management

Web-assisted self-management interventions employed mechanisms for sustaining participation and provided personalized, immediate, or frequent feedback.[35,38,53,72,80,86–91] The issue of attrition has been addressed in a number of ways, with significant improvements in retention when the intervention was provided as an adjunct to routine care[92] or when interactivity increased.[93,94] Stage-based interventions have been found to increase physical activity,[95] whereas others found action-based messages and ethnically appropriate messages beneficial in increasing engagement.[38]

Which Intervention Features Are Most Useful?

Patients across studies rated several features favorably. These included the ability to log and track blood glucose values,[13,28,35,66,96–98] receive electronic reminders,[63,66,72,74,85,99] schedule physician visits,[63,72,85] access relevant disease-specific information,[65,74,99] email the health care team,[66,68,85,96,98] get quick responses via email from staff,[68,72,99] and form special interest groups with other members.[38,68]

Key Issues

A number of recurring observations emerged from the studies reviewed. Ultimately, the goal of these interventions was to help patients reach clinical targets. The overarching challenge that seemed to emerge from this review was the limited ability to determine which intervention features are most effective.

Research Design

Sample sizes tended to be small and may not represent the populations in question adequately, which limits the generalizability of results. However, it is encouraging that ethnic minorities,[38,39,46] Medicare recipients,[33,46] and the elderly[42,52,55] participated at a rate comparable to traditional interventions.[14] Few studies presented long-term results. Sixty percent of the studies were less than 6 months in length. It is important to determine if short-term results can be maintained over time.

Decreased Use

Web site use often decreased over time. It has been shown fairly consistently that improvement in clinical outcomes is directly proportional to dose.[14,100] A closely related issue is attrition.

Attrition

Technical difficulties experienced by patients have been shown to be a major contributor to attrition.[48,101] To address this, participants require assistance in overcoming technical issues early in the intervention and need to be monitored closely. Rewarding participants with gift certificates upon completion of tasks has successfully decreased attrition.[38]

Self-Selection

Patients who choose to participate in programs tend to be more computer literate and more highly educated.[68,71] This brings to the fore the question of whether people who are in most need of these interventions are being reached by these programs or whether Web delivery really improves access.[102] However, the Diabetes-Net and IdeaTel projects overcame this barrier and successfully recruited participants that were representative of their target populations. Participants were recruited from the office of their primary care physician or were invited to participate by their primary care physician.[44,46]

Behavior Change Framework

A recent meta-analysis of diabetes self-management interventions found that only one-third used a behavioral theory or model.[103] Programs based on sound behavioral theory have an increased probability of maximizing the effective application of Web-based technology.[14,50,104–111]

Sustainability at the Organizational Level

Web-assisted interventions found in current diabetes management literature may have limited applicability to clinical settings where most care is provided.[112] Major projects tend to be government funded. Mechanisms to implement and sustain these systems in different practice settings need to be developed if widespread adoption is to occur.[66-68,112]

The Chronic Care Model as described by Wagner and colleagues[113] may provide a solution. The model contains six interdependent elements that serve to meet provider and patient needs with the goal of adherence to established clinical guidelines. The elements are evidence-based guidelines, practice redesign, patient education, expert system, and information. Each element can be facilitated by Web-based systems. Many features of the model overlap. Evidence-based guidelines have been used to generate clinical reminders for medical staff, design automated feedback, notify clinical staff values requiring timely intervention, and form the basis of treatment and/or decision support algorithms. Practice redesign most often shifted roles from physician to nurse and from clerical staff to an automated system. The net effect is that physicians can spend less time looking for data and have clinical guidelines readily available. Web-based patient education was the component of the model used most often. Numerous interventions required active patient participation for uploading data, responding to IVR, or entering information into diaries. The expert system element was the least-used component of the model. It is the most expensive to design and implement. The information element of the model utilized email, SMS, and telephone to contact patients.

Adoption of Chronic Care Model elements has been shown to improve the quality of care and increase the sustainability of comprehensive diabetes management programs.[30,36,50,88,99,114–119] Implementation of a single model element can improve clinical outcomes in patients suffering from chronic illness.[120]

Table 1 summarizes how elements of the model have been utilized in diabetes management interventions. The chronic care model was not used to structure the majority of the interventions listed. However, intentional application of model elements in the design of Web-based diabetes interventions may potentially increase adoption and improve the quality of care and clinical outcomes.[117–120]

A case in point follows: a successful hospital-based diabetes management program operating since 1997 attributes three factors to its sustainability.[88] First, administrators took a long-term view of the program. Cost savings were not expected immediately. Second, processes were restructured to utilize staff and facilities effectively. Third, evidence-based guidelines were used to structure care delivery. The last two items are consistent with the chronic care model.[113,117–119]

Barriers to Implementation

Barriers to implementation of Web-based medical or self-management interventions in diabetes occur at several levels. Five major types of barriers must be overcome. First, cost is frequently cited as a barrier to design, implementation, and sustainability of Web-based systems and needs to be examined more thoroughly.[27]

The second barrier is failure to develop interventions that consider patient or staff characteristics in the design phase. These characteristics may have moderating effects on participation in Web-assisted care, clinical outcomes, or sustainability. Examples include functional literacy,[121] health literacy,[122] eHealth literacy,[123] computer literacy of the medical staff,[124] patient computer literacy,[53] cultural relevance,[125–128] patient expectations,[111,129] patient satisfaction,[114] and provider satisfaction.[130]

Third, evidence-based guidelines improve clinical outcomes. However, current medical practices and hospitals may require a redesign of internal processes to facilitate implementation of the guidelines. Examples from the studies reviewed are decision support systems or prompts delivered as orders are written[48,57,85] or delivered when instructions are given to the patient.[77] Computer-based systems have the ability to seamlessly integrate clinical monitoring, medical records, medical management, and patient education.[57,62–64,67,131,132]

Fourth, patients and medical professionals express concern about confidentiality. These concerns have limited the acceptance of Web-based communication, particularly email with patients.[133] Data privacy and security were cited in a recent review as barriers to implementation of Web-based chronic disease programs.[27]

Fifth, payment policies must be changed to make disease management services billable. In most cases, physicians and facilities are unable to bill for time spent on Web-based diabetes care. Financial incentives to participate in these activities are lacking.[134–136] Legislation is currently under consideration at the federal level that would remove this barrier from Medicare.[135] There is some indication that payment for these activities can be recouped in system-wide health care cost savings.[136]

Areas for Future Study

Future studies need to answer a fundamental question: "Which technology is most effective for which person, under what circumstances, and why?"[103,104] While we

Table 1.
Chronic Care Model Features Utilized in Interventions Delivered Via the Web

Elements [a]		Model examples [a]	Web interventions examples
1	Evidence-based guidelines		Standards of care for diabetes[56] JNC 7 high blood pressure[82] National cholesterol guidelines[83]
2	Practice redesign	Appointments Roles Follow-up	High-risk patients selected from pharmacy database[58] Computerized registry used to select high-risk patients[59] Nursing staff case management[33–36,45,46,55,72,78,86,89,96,98,99] Retinopathy screening or wound monitoring[62–65] Staff prompted when EMR registers out-of-range hemoglobin A1c [77] Clinical staff emails patients[130] Patient phoned when uploaded data out of range[86,131] Reports generated for MD use during patient visit[48,101] MD sets clinical targets for patient alarms[48]
3	Patient education	Self-management Behavioral change Psychosocial support Patient participation	Patients transmit data into EMR[32,39,45,46,55,72,73,78,89,96,98] Patients access website information[35, 38,42,43, 44,45,46,55,89,131] Low literacy diabetes education[121] Tailored self care[13,40] Self-management support group[17,18,24,38,42,44,73] Electronic diary to record food intake and/or physical activity[42,72,131]
4	Expert system	Provider education Decision support Consultation	Clinical decision support tool[48,57] Staff receive and evaluate uploaded data[32,35,39, 45,46,55,79,80,89,97,131] Clinical recommendations emailed to physician based on patient data[32,59] Computer-generated feedback to patient after data upload[73] Automated SMS messages from data upload[93] Care reminders generated from EMR data and delivered for physician use at point of care[84,85]
5	Information	Reminders Outcomes Feedback Care Planning	Physician emailed clinical recommendations based on evidence-based guidelines[59] Videoconference for care planning and feedback[45,46, 55,78,96] Web-based screening for retinopathy and wound monitoring[62–65] Point of care reminders[77,101,184] Patients receive SMS feedback about uploaded data[35,79,80,97,131] Patients receive emailed feedback about uploaded data[38,42,89] Patients emailed nursing staff[72,89]

[a] Adapted from Wagner *et al.*[113]

have made progress in understanding important issues in designing Web-based diabetes management, there are still a number of areas that need further empirical investigation. Recommendations will be made in the areas of behavior change, effect of individual characteristics, selection of appropriate technology, and cost-effectiveness.

Theoretical Frameworks

The ultimate goal of diabetes care is behavior change that produces improved clinical outcomes. Structuring interventions based on sound behavioral theory will increase the likelihood of success.[79,82,104] Frameworks for technology adoption also need to be applied to these systems.[137,138]

Effect of Individual Characteristics

Further study is also needed to determine which individual characteristics affect use and level of engagement with Web-based interventions.[24,50,51,54,103,104] These include psychosocial variables,[52,90,108,109,140] level of adherence,[106,107,131] literacy,[41,121–123] age,[46,52] ethnicity,[38,39,58,71,102,110,125–128] determinants of satisfaction that impact attrition,[14,104,129] self-efficacy,[13,37,121] baseline hemoglobin A1c,[42,34,36] comorbid conditions,[32–34,42,139–141] and depression.[44–47,55,105,140]

Selection of Appropriate Technology

Technology should be selected to facilitate the goals of the intervention. The mechanics of this process need

further study. The incremental effect of support groups, chat, and discussion boards on behavior change remains poorly understood.[18,82,83,105,106] This was the focus of a well-designed study by Glasgow and colleagues[44] where the incremental effect of adding a personal coach and/or social support on clinical outcomes was explored. Clarification of how technological features affect outcomes in specific populations or enhance provider adoption will ultimately decrease development costs.[134–139]

Cost-Effectiveness

Methods to assess program development costs and overall cost-effectiveness need to be designed and validated. This will facilitate accurate comparison of studies. Health services research protocols may be useful in determining the cost-effectiveness of Web-based interventions.[136] Significant clinical outcomes and cost savings have been demonstrated in European systems that have successfully linked Web-based components to comprehensive disease management programs.[101]

Conclusion

Technological capability has increased rapidly. However, well-designed trials to determine how best to use the technology and that address public policy have not progressed at the same rate. Results from randomized controlled trials and carefully designed, nonrandomized trials can provide valuable information. Comprehensive systems that link medical management to self-management with the electronic medical record have consistently shown significant improvement in clinical outcomes and cost savings. These systems, however, have not been adopted widely.

Contrary to common beliefs about inertia with regards to patients' adoption of diabetes care technology, patients generally comply with expectations to collect and upload clinical data. This is consistent in older adults, across countries, socioeconomic levels, and ethnicities. However, clinicians have not always responded to uploaded EMR data with timely review and feedback. In this regard, programs have been found to work best when staff is specifically assigned to support Web-assisted interventions. Design, implementation, and maintenance of effective Web-based diabetes management systems may best be accomplished by the collaboration of patients, clinicians, engineers, private/public payers, and professionals skilled in facilitating organizational change. To foster this, the Chronic Care Model provides a workable framework for developing sustainable systems that meet the needs of both patients and medical staff.

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