A Systematic Review of Interactive Computer-assisted Technology in Diabetes Care Interactive Information Technology in Diabetes Care

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Abstract
BACKGROUND
Excellent diabetes care and self-management depends heavily on the flow of timely, accurate information to patients and providers. Recent developments in information technology (IT) may, therefore, hold great promise.
OBJECTIVE
To determine, in a systematic review, how emerging interactive IT has been used to enhance care for adults with type 2 diabetes.
METHOD
Eligible studies were randomized controlled trials (RCTs) and observational studies (both before-after designs and post-intervention assessments) focused on computer-assisted interactive IT that included ≥10 adults with diabetes (≥50% type 2) and reported in English. We searched 4 electronic databases (up to 2003) using terms for diabetes and technology, reviewed bibliographies, and handsearched *Diabetes Care* (January 1990 to February 2004). Two reviewers independently selected articles and worked serially on data extraction with adjudication of discrepancies by consensus.
RESULTS
There were 26 studies (27 reports): internet (*n*=6; 3 RCTs), telephone (*n*=7; 4 RCTs), and computer-assisted integration of clinical information (*n*=13, 7 RCTs). The median (range) sample size was 165 (28 to 6,469 participants) for patients and 37 (15 to 67) for providers; the median duration was 6 (1 to 29) months. Ethnic minorities or underserved populations were described in only 8 studies. Six of 14 interventions demonstrated moderate to large significant declines in hemoglobin A1c levels compared with controls. Most studies reported overall positive results and found that IT-based interventions improved health care utilization, behaviors, attitudes, knowledge, and skills.
CONCLUSIONS
There is growing evidence that emerging IT may improve diabetes care. Future research should characterize benefits in the long term (>1 year), establish methods to evaluate clinical outcomes, and determine the cost-effectiveness of using IT.

Keywords: type 2 diabetes, information technology, computer, internet, self-management, clinical management, interactive, systematic review

Tight control of blood glucose to either prevent or delay the progression of diabetes-related complications relies heavily on patient behavior modification and proper guidance/education from health care professionals.[1] Information technology (IT), such as the computer, internet, multimedia, and other forms of electronic communication, holds great promise to influence diabetes care positively. Information technology provides an avenue for the rapid and easy dissemination of information to patients and clinicians as well as allows interactive communication between the patients and their health care provider teams.[2] Despite the well-recognized potential of IT in health care, there has been little systematic evaluation of its present impact on the health care system.[3]

Several reviews have evaluated various IT interventions in type 1 diabetes care. Balas et al.[4] evaluated computerized interventions to enhance diabetes management and reported positive outcomes for 12 (80%) of the 15 trials, including improved hemoglobin A1c (HbA1c), blood glucose, and hypoglycemic events. Another review, conducted by the same author, evaluated 40 computer-assisted interventions and concluded that the majority showed significant improvements in glycated hemoglobin, blood glucose, guideline compliance, and reductions in hypoglycemic events and insulin doses.[5] Glasgow and Bull[6] discussed the strengths and limitations of various technologies used to augment diabetes self-management education. Although not a formal systematic review, the article suggested that technology should help diabetes educators reach and support more people, and that health behaviors seemed to be more positively affected than biological outcomes.

Although the conclusions drawn from these articles are relevant, they evaluated mainly type 1 diabetes and the objectives of the reviews were limited.[4–6] Both review articles focused solely on the use of IT for diabetes self-management without considering how IT would be incorporated into clinical practice.[5, 6] Additionally, no reviews to date have reported ethnic minority participation rates or costs of IT interventions. Therefore, the goals of this systematic review were to: (1) provide an up-to-date assessment of the literature, (2) summarize the effects of interactive IT on several health care and clinical outcomes in type 2 diabetes samples, (3) assess the inclusion of ethnic minority populations, and (4) report costs associated with the interventions.

METHODS

Eligibility Criteria

Eligible studies were published randomized controlled trials (RCTs) or observational studies (nonRCTs, pre-post studies, and post-only studies) that implemented interactive technology as the main component of an intervention for diabetes care (all forms of IT were computer assisted). The review was limited to interactive interventions because of their potential to impact diabetes care by prompting action from the provider and/or patient. Eligible studies were published in English and studied ≥10 adults (≥18 years old) with diabetes, of whom ≥50% had type 2 diabetes.

Search Strategy

Published studies were identified by searching the electronic databases PubMed, PsycINFO, CINAHL, and Cochrane Library through 2003. The following keywords were used for each database: diabetes or noninsulin-dependent diabetes AND internet, internet-based, electronic, intervention, RCT, therapy, education, programs, techniques, impact of, and behavior. The

search was limited to human subjects and the English language in the PubMed database. Additional strategies included searching bibliographies of eligible studies, a hand-search of the journal *Diabetes Care* from January 1990 to February 2004, and a *related articles* search in the PubMed database during the abstract review.

Data Abstraction

Titles and abstracts were independently reviewed by 2 investigators and if eligible, full articles were then abstracted by serial review. One investigator completed the standardized data abstraction form and a second investigator reviewed it for accuracy and completeness. If at any time both investigators could not resolve differences (i.e., eligibility criteria, interpretation of results), conflicts were adjudicated by a third investigator.

Data Synthesis

Because of the heterogeneity of the studies and the small number of articles in each category, we did not conduct a metaanalysis. Rather, we summarized the studies qualitatively, noting the outcome data in tables.

RESULTS

Search Strategy

Figure 1 describes the search outcomes. We found 27 eligible articles, which described 26 interventions (2 articles described 1 intervention).[7, 8]

Description of Study Characteristics

Table 1 describes the included studies. Publication dates ranged from 1984 to 2003 (16 articles published in the last 3 years). The median age (range) for study participants was 59 (43 to 70), the median percentage for male participants was 47% (23% to 95%), and 86% (50% to 100%) for type 2 diabetes patients. The median sample size was 165 (28 to 6,469) for patients and 37 (15 to 67) for providers. The median intervention duration and follow-up time period was 6 (1 to 29) months.

Eight studies reported inclusion of ethnic minorities (see Table 1), in which the median was 39% (5% to 74%).[7, 9–15] One study reported a population of 11% Asian Pacific Islanders.[14] Of the 8 studies, 1 focused exclusively on Hispanics[9] and 1 predominantly on African Americans (86%).[12]

Description of Intervention Characteristics

In general, the studies sought to evaluate the effectiveness of technology-enabled programs to improve diabetes education, clinical outcomes, patients' perceived quality of life and support, as well as patient and provider processes of care (visits, testing, and documentation of adherence).

Articles were placed into 3 categories based on the main focus of the IT intervention: internet, telephone, and computer-assisted integration of clinical information. The studies in the internet category used interactive web technology to enhance patient self-management and clinical management by providing diabetes education and feedback of resulting data. Articles in the telephone category used interactive, automated telephone calls and telemedicine to enhance patient self-management through self-care education calls and feedback of self-monitored information to the provider. Articles in the computer-assisted integration of clinical information category consisted of computerized patient education and interventions that integrated electronic practice guidelines, reminder systems, and feedback of clinical data to enhance both self and

clinical management. All 3 categories included technology focusing on self and/or clinical management and differed mainly by their mode of delivery.

Clinical Outcomes

Studies measured clinical outcomes such as HbA1c levels, body weight, blood pressure, microalbumin, creatinine, lipids, depression, and hematocrit values. Six of 14 studies demonstrated significant declines in HbA1c levels among intervention groups[12, 16–20] (Table 1). One intervention from the internet category measured HbA1c and showed a small, nonsignificant decline.[21] Interventions in the telephone category showed moderate or large declines although only three of the 16 studies were statistically significant. Studies in the computer-assisted integration of clinical information category had mixed results.

Studies that reported outcome data on change in body weight,[10, 11, 12, 16, 17, 20, 22] blood pressure,[11, 12, 23, 24] microalbumin,[12, 20, 24] and creatinine[20] generally found no significant difference between intervention and control groups. Studies that evaluated lipids[10, 11, 12, 20, 21, 23, 24, 25] and depression[13, 21] found both significant and nonsignificant decreases.

Health Care Utilization

A summary of health care utilization outcomes (n=8) is shown in Table 2. Although there were mixed results regarding hospitalizations,[9, 16] a number of studies reported an increase in foot exams[7, 15, 23, 24] and HbA1c tests,[23, 24, 26] as well as favorable outcomes with regard to primary care visits.[7, 9, 15, 16, 19] The 2 studies that reported decreases in primary care visits were both associated with favorable outcomes. One study used a device (i.e., health buddy technology) implemented for daily collection of information from participants. This service allowed the provider to identify problems and intervene before a crisis occurred, which is believed to have resulted in a desired decrease of visits.[9] Another study decreased clinic visits 2-fold by using an electronic case manager (ECM) system to facilitate management of glycemic control.[19] One of the 4 interventions evaluating the number of eye exams performed[7, 15, 24, 26] produced significant increases. Health care utilization was not evaluated by interventions in the internet category, and studies in the telephone category found no change in hospitalizations and eye exams, mixed results with regard to foot exams, and favorable results in terms of primary care visits. Lastly, the computer-assisted integration of clinical information interventions showed a decline in hospitalizations, favorable outcomes for primary care visits, foot exams, and HbA1c tests, and mixed results in eye exams.

Costs

Costs associated with the interventions were reported by 9 studies (Table 3)[9, 11, 15, 16, 17, 19, 26, 27, 28]; most authors did not report itemized costs. The majority of the articles reported the costs of the systems used to conduct the interventions, which ranged from $5.00 per patient to $6,340 for the complete system (i.e., computer, PDA, telemedicine, etc.). Lastly, none of the studies from the internet category, 4 of the 7 studies in the telephone category,[11, 15, 16, 19] and 5 of the 14 studies in the computer-assisted integration of clinical information category reported costs associated with the interventions.[9, 17, 26, 27, 28]

Other Outcomes

The studies that evaluated behaviors generally found better postintervention self-reporting and documentation of diabetic crises, moderate use of interventions, and high rates of completion after the intervention.[7, 9–16, 18, 19, 21, 23, 25, 26, 28–32] Studies that measured attitudes produced an

overall increase in patients' satisfaction with the interventions, personal health care, perceived support, and quality of life.[7, 9, 10, 11, 13, 14, 15, 20, 25, 26, 28, 31, 33] Several studies (*n*=8) assessing knowledge found an overall increase in patients' understanding of their medical condition.[9, 14, 15, 18, 22, 27, 28, 30] Furthermore, studies (*n*=4) evaluating patient skills reported that the interventions were easy to use and understand, which typically resulted in short instruction time[9, 18, 30, 32] (data not shown).

DISCUSSION

The results of this review add to the growing body of evidence that emerging IT may assist with improving health outcomes related to diabetes. Information technology appears to be a developing tool to improve the process of care for type 2 diabetes patients, as indicated by the significant improvements in health care utilization. Nonetheless, there were mixed results regarding declines in HbA1c levels and the other clinical outcomes (i.e., lipids). Although these findings are consistent with the reviews in type 1 diabetes in terms of psychological and biological outcomes,[6] a formal metaanalysis conducted by Montani et al.,[34] which also focused mainly on type 1 diabetes, supports the hypothesis that computer-based systems can effectively improve metabolic control.

By mode of delivery, internet interventions had a positive impact on patient-centered outcomes, but generally did not evaluate health care utilization and clinical outcomes. Telephone interventions had a positive impact on primary care visits. Computer-assisted integration of clinical management had a positive effect on most of the health care utilization outcomes. Although several interventions produced large declines in HbA1c, there was no clear pattern by mode and many studies reported no significant change in HbA1c.

The results of this study should be interpreted with several limitations in mind. First, only published studies were reviewed; this introduces the possibility of a publication bias. Second, the heterogeneity of the studies weakened any general inferences and prevented a metaanalysis, which could have allowed for a more quantitative assessment. Finally, only articles written in the English language were reviewed. However, broad inclusion/exclusion criteria were used to increase the likelihood of capturing relevant studies, including a hand search of *Diabetes Care* and a *related articles* search for completeness. Furthermore, double review was conducted to minimize errors and increase accuracy in data abstraction. Finally, to our knowledge, this is the first IT review to address type 2 diabetes specifically.

A recent review conducted by Farmer et al.[35] evaluated the feasibility, acceptability, and effectiveness of telemedicine used to support blood glucose self-monitoring via transmission of results through a remote server, with automated or clinician feedback. Results showed that telemedicine was deemed feasible and acceptable, but evidence for its effectiveness in improving diabetes management was not considered robust. Although the review's primary focus and inclusion/exclusion criteria led to a pool of studies that differed from this review, the results are consistent with our findings related to telemedicine interventions and HbA1c.

This review provides several implications for future research in IT use in diabetes. First, there needs to be improvement in the quality of studies and reporting of results. Based on this review, we strongly recommend that future studies (1) favor RCT designs that enable comparisons with a

concomitant control group with less biased assessment of the effectiveness of these interventions; (2) study the long-term (>1 year) effects of these interventions; (3) address and report on the costs associated with the intervention and the resulting cost-effectiveness; and (4) include representative numbers of ethnic minorities and underserved populations and determine whether these interventions are equally effective in these groups. Second, studies should consider participants' perceptions of IT as diabetes self-management as IT will likely remain an integral component of care that depends on the acceptance of the patient. In addition, internet-assisted interventions, which generally focused on patient education, should evaluate HbA1c, health care utilization, and costs associated with the intervention.

Overall, financial support for further research in this area seems promising as the studies in this review were funded by a number of sources including: the National Institutes of Health, National Library of Medicine, professional organizations, and private foundations.

In conclusion, our review suggests that computer-assisted interactive IT could be an important tool and should be evaluated more closely for its potential to improve diabetes care.

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