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Contents

Review

The Contribution of Teleconsultation and Videoconferencing to Diabetes Care: A Systematic Literature Review

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Abstract

Background: A systematic literature review was carried out to study the benefits of teleconsultation and videoconferencing on the multifaceted process of diabetes care. Previous reviews focused primarily on usability of technology and considered mainly one-sided interventions.

Objective: The objective was to determine the benefits and deficiencies of teleconsultation and videoconferencing regarding clinical, behavioral, and care coordination outcomes of diabetes care.

Methods: Electronic databases (Medline, PiCarta, PsycINFO, ScienceDirect, Telemedicine Information Exchange, ISI Web of Science, Google Scholar) were searched for relevant publications. The contribution to diabetes care was examined for clinical outcomes (eg, HbA_{1c}, blood pressure, quality of life), behavioral outcomes (patient-caregiver interaction, self-care), and care coordination outcomes (usability of technology, cost-effectiveness, transparency of guidelines, equity of care access). Randomized controlled trials (RCTs) with HbA_{1c} as an outcome were pooled using standard meta-analytical methods.

Results: Of 852 publications identified, 39 met the inclusion criteria for electronic communication between (groups of) caregivers and patients with type 1, type 2, or gestational diabetes. Studies that evaluated teleconsultation or videoconferencing not particularly aimed at diabetes were excluded, as were those that described interventions aimed solely at clinical improvements (eg, HbA_{1c}). There were 22 interventions related to teleconsultation, 13 to videoconferencing, and 4 to combined teleconsultation and videoconferencing. The heterogeneous nature of the identified videoconferencing studies did not permit a formal meta-analysis. Pooled results from the six RCTs of the identified teleconsultation studies did not show a significant reduction in HbA_{1c} (0.03%, 95% CI = - 0.31% to 0.24%) compared to usual care. There was no significant statistical heterogeneity among the pooled RCTs (χ^2_7= 7.99, P = .33). It can be concluded that in the period under review (1994-2006) 39 studies had a scope broader than clinical outcomes and involved interventions allowing patient-caregiver interaction. Most of the reported improvements concerned satisfaction with technology (26/39 studies), improved metabolic control (21/39), and cost reductions (16/39). Improvements in quality of life (6/39 studies), transparency (5/39), and better access to care (4/39) were hardly observed. Teleconsultation programs involving daily monitoring of clinical data, education, and personal feedback proved to be most successful in realizing behavioral change and reducing costs. The benefits of videoconferencing were mainly related to its effects on socioeconomic factors such as education and cost reduction, but also on monitoring disease. Additionally, videoconferencing seemed to maintain quality of care while producing cost savings.

Conclusions: The selected studies suggest that both teleconsultation and videoconferencing are practical, cost-effective, and reliable ways of delivering a worthwhile health care service to diabetics. However, the diversity in study design and reported findings makes a strong conclusion premature. To further the contribution of technology to diabetes care, interactive systems should be developed that integrate monitoring and personalized feedback functions.

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KEYWORDS

Chronic diseases; diabetes mellitus; telemedicine; consultation; teleconsultation; videoconferencing

Introduction

Diabetes mellitus (DM) is major chronic disease that demands teamwork from various caregivers for the delivery of high-quality care [1]. Consequently, an adequate communication structure is an important condition for optimal interaction and coordination among caregivers and between patients and caregivers [2]. Information and communication technology (ICT) is often seen as the solution for problems in the management of diabetes care because of its potential to enhance care coordination and support patient self-care [3]. It is expected that using ICT will reduce costs while maintaining high-quality health care and that ICT can respond to an increasing demand for care with a decreasing availability of personnel [4]. Previous reviews on diabetes care have found modest benefits of ICT-based care compared to conventional face-to-face care. However, these reviews focused primarily on the usability of technology and considered mainly one-sided interventions such as clinical improvements (glucose and diet) rather than looking at the multifaceted process of a diabetic patient, including relevant issues such as the influence of interactive technology on the process of care (patient-caregiver collaboration, care coordination, costs) and patient outcomes such as quality of life and self-care [2,4,5].

ICT-based care is more than just a technological intervention—it includes a way of thinking about how to deliver health care with the aid of ICT [6]. The most important modalities of ICT-based care are teleconsultation and videoconferencing [1]. Teleconsultation is a kind of telemonitoring including patient-caregiver communication (monitoring and delivering feedback) via email, phone, automated messaging systems, other equipment without face-to-face contact, or the Internet [7]. Videoconferencing involves real-time face-to-face contact (image and voice) via videoconferencing equipment (television, digital camera, videophone, etc) to connect caregivers and one or more patients simultaneously, usually for instruction [8].

The aim of this review is to obtain an overview of the existing empirical support for the alleged benefits of teleconsultation and videoconferencing on diabetes care. The benefits are evaluated by means of criteria for "good chronic care" [1,2]. The evaluation criteria are clinical outcomes, behavioral outcomes, and care coordination outcomes [1,2]. Clinical outcomes include metabolic control and of life. Behavioral outcomes include self-care and patient-caregiver interaction. Care coordination outcomes refer to cost-effectiveness, transparency of the care delivery process, equity of access to care, and usability of equipment to facilitate the care delivery process.

Our review is intended to inform social scientists and practitioners about the potential of technology to improve diabetes care. We provide an overview of what is currently known about the benefits and deficits of teleconsultation and videoconferencing and how practical and worthwhile these services are [9].

Methods

Literature Search

We collected publications (from May 2005 to December 2007) on empirical research on ICT-based interaction between caregivers and patients or groups of patients, or among caregivers or patients themselves, using the for systematic reviews developed by the Centre for Reviews and Dissemination [10]. The review was restricted to studies evaluating teleconsultation and/or videoconferencing developed for type 1, type 2, and/or gestational diabetes and to language publications published between 1994 and 2006.

No restrictions were imposed on the quality of study design because assessment studies dealing with ICT-based care are scarce [9], and, in practice, reviews have been constrained by the availability of data. In particular, behavioral or care coordination aspects were seldom the focus of reviews on diabetes care. Most reviews focused solely on clinical values in randomized controlled trials (RCTs). In light of a holistic approach, we wanted to provide a broad range of information in order to facilitate decisions about implementing new technology in health care. We excluded studies dealing with broader target groups than diabetics, studies not aimed at patient-caregiver interaction but solely reporting technical aspects of the equipment used, and those that strived for clinical improvements only. We included studies that covered clinical outcomes plus one or more other outcomes (behavioral, care coordination).

The following electronic databases on medicine, psychology, and telemedicine were searched: Medline, ScienceDirect, ISI Web of Science, Telemedicine Information Exchange, PsycINFO, PiCarta, Google Scholar, and journal indexes (Diabetes Care, Effective Health Care, Journal of Medical Internet Research, Journal of Medical Informatics, Telemedicine and E-health, Telemedicine and Telecare). Keyword sets combined "diabetes" and one of the following: "telemedicine," "telecare," "telehealth," "e-health," "teleconsultation," "telemonitoring," or "videoconferencing." We used "telemedicine" because the terms "e-health" and "electronic care" were hardly used in the literature before 2004. In addition to the databases, the reference lists of the identified publications were hand-searched. Citation was reviewed and designated as "in," "out," or "uncertain" based on the aforementioned restrictions. Sources designated as “in” or “uncertain” were obtained for further review. Two of the authors independently reviewed titles and abstracts of the identified publications to decide whether they should be examined in full detail.

Two authors completed data extraction forms developed by the Centre for Reviews and Dissemination [10] and recorded the following details: study design (evidence level and methods for measurement outcomes, patient selection, description of intervention and control groups), study population (type of diabetes, age group, number and recruitment of patients), and intervention details (care setting, technology used to support the care delivery process, duration of the intervention). Using the care levels previously mentioned (clinical, behavioral, and care coordination) [1,2], we developed a checklist to categorize the outcomes of the interventions (Table 1).

Table 1. Checklist to classify the outcome measures related to the levels of diabetes care

Level of Diabetes Care	Outcome Measures
Clinical	• Improved clinical values (eg, dietary values, HbA_{1c} , blood pressure) • Improved quality of life (social functioning, general or mental health, well-being, and satisfaction with care)
Behavioral	• Improved interaction (communication between caregivers and patients or among caregivers or patients themselves) • Improved self-care (ablity to control diabetes and to cope with diabetes via self-monitoring, education, knowledge about diabetes, and personal feedback)
Care coordination	• Improved usability (and adoption) of technology • Reduction of costs (saving patients’ or caregivers’ time and reducing the use of health care services) • Improved transparency (care delivery based on standards as guidelines, protocols for information exchange) • Improved equity (the availability of health care to everyone)

Five levels [10] were used to categorize the methodological approaches of the studies (Table 2). Two authors independently rated the study designs. In case of disagreement, consensus was reached by discussion.

Table 2. Checklist to categorize level of evidence of study design

Level of Evidence	Study Design
1	Experimental studies (eg, RCT with blinded allocation)
2	Quasi-experimental studies (eg, experimental study with randomization)
3	Controlled observational studies
3a	Cohort studies
3b	Case control studies
4	Observational studies without control groups
5	Expert opinion based on bench research or consensus

Statistical Methods

A quality assessment was completed for all RCTs using the Jadad scale [11]. This scale contains questions about randomization, blinding, and withdrawals that are scored by a yes (1) or no (0). In total, five points can be awarded, with higher points indicating higher study quality.

Changes in HbA_{1c} values were calculated from baseline and follow-up means and standard deviations. Only studies researching effects on adults were included in the meta-analysis. When the deviation of the mean difference was not available in the papers, the authors were contacted. In case of no response or no availability of the requested information, we estimated the variance by using (1) reported confidence intervals, (2) reported *P* values, or (3) an imputation technique [12]. A random-effects model was used for pooling the included studies because clinical heterogeneity between studies was expected. The between-study heterogeneity was tested using the chi-square statistic. In one study, three intervention groups and one control group were studied. In meta-analyses, all three intervention groups were compared with the same usual care group, resulting in two extra comparisons.

Results

Study Characteristics

We identified 852 potentially relevant publications, 39 of which were included after the selection procedure described in the previous section (Figure 1).

Figure 1. Study selection process

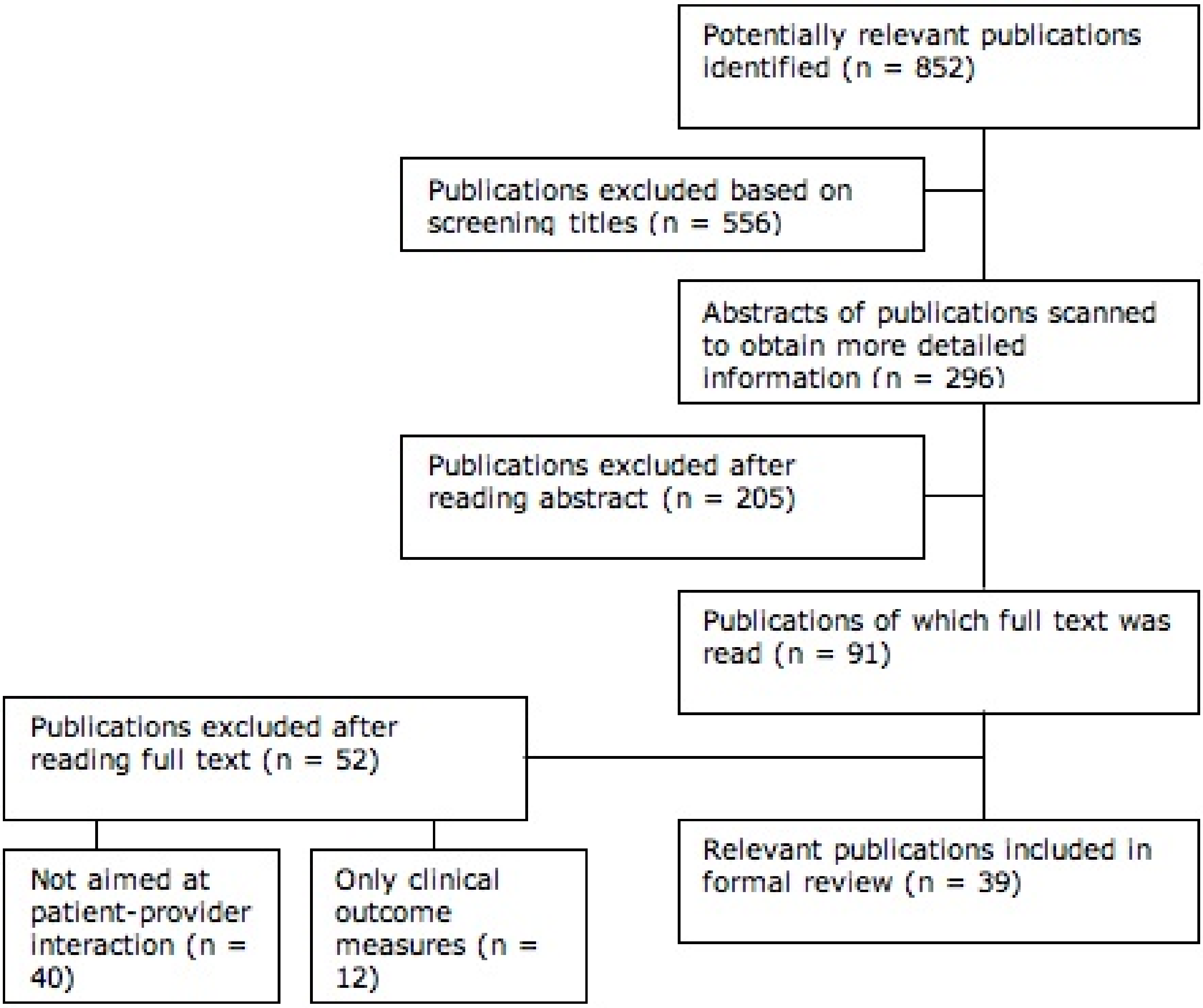


Table 3 (teleconsultation) and Table 4 (videoconferencing) summarize the characteristics of the publications that were included. As can be seen, 22 interventions addressed teleconsultation [13-34], 13 addressed videoconferencing [35-47], and 4 addressed videoconferencing combined with teleconsultation [48-51]. The most frequently used methodological approach was observational (case series or before-after design), which was used in 19 studies; 11 studies were RCTs, and 6 were quasi-experimental. The other methodological approaches were used only incidentally (two cohort studies and one study based on expert interviews). Sample sizes included ≤ 20 (n = 9), ≤ 100 (n = 17), > 100 (n = 12), and one was not specified. Participants were selected by the research team [31,33,36,47,49,50], general practitioner [17,30,35,47], a specialist [15,17,22,24], or via convenience sampling [32,40].

Data were gathered via interviews, focus groups, log files, and nonstandardized questionnaires. Validated questionnaires were used in 12 of the 39 studies to measure usability of technology, quality of life, and self-care. The Telemedicine Satisfaction Questionnaire [14,25,41,47] was used for measuring usability of technology. Quality of life was measured with various questionnaires: the World Health Organization Quality of Life-BREF [14], SF-12 [17,25,30], SF-36 [36,38,41,44,48,49], Diabetes Quality of Life [25,30,36,41,44], Depression Scale CES-D [30], Problem Areas in Diabetes Scale [41], and the Visual Analog Scale [26]. The Diabetes Knowledge Assessment [36], Diabetes Treatment Satisfaction Questionnaire [41], and the Appraisal of Diabetes Scale [41] were used to measure self-care.

Table 3 and Table 4 present the improvements found in the studies, per outcome (clinical values, quality of life, patient-caregiver interaction, self-care, usability, cost reduction, transparency, and equity). Most of the studies reported improvements in usability of technology (n = 26; 15 teleconsultation and 11 videoconferencing), followed by clinical improvements (n = 21; 15 teleconsultation and 6 videoconferencing), cost reduction (n = 16; 5 teleconsultation and 11 videoconferencing), self-care (n = 14; 10 teleconsultation and 4 videoconferencing), and patient-caregiver interaction (n = 13; 10 teleconsultation and 3 videoconferencing). A minority of the studies reported improvements in quality of life (n = 6, 3 teleconsultation and 3 videoconferencing), transparency of care delivery guidelines (n = 5, 3 teleconsultation and 2 videoconferencing), and equity in access to health care (n = 4; all videoconferencing).

The findings summarized in Table 3 and Table 4 were extracted from publications that varied in study design and data gathering methods, and the reported findings were often not substantiated with evidence, as can be seen in the tables. In the light of the purpose of our review, we took this heterogeneity in study characteristics into account.

To get insight into the contribution of teleconsultation and videoconferencing to diabetes care, the results of these interventions were presented separately, describing care setting and intervention and clinical, behavioral, and care coordination outcomes. Improvements were reported and explained.

Table 3. Overview of teleconsultation interventions (see Multimedia Appendix for full tables containing inclusion criteria and data gathering methods)

Reference, Country, Year, and Duration of Intervention	Care Setting and Intervention	Study Design	Reported Findings (Improvements) *
[13] • Italy/Spain/Norway • 2002 • 18 months, follow-up planned (duration unknown)	Secondary care. Blood glucose meter to send clinical data and lifestyle data (every 7 to 10 days) via telecommunication system (Internet / telephone line). Daily computer-generated feedback is provided, and, if necessary, messages from physician (specialist in hospital) to advise patients. No details provided about feedback system and frequency of feedback.	• Observational studies without control group: n = 32 • Four conditions: 1. Verification phase: clinical evaluation (n = 3) 2. Pilot clinical validation (n = 12) 3. Demonstration phase: Intranet (n = 6) 4. Demonstration phase: Internet (n = 11)	
[14] • Italy/Spain/Germany • 2003 • 12 months, follow-up unknown	Integrated care. Reflectometer and palmtop to transmit clinical data via multi-access system (Web access, telephone, interactive voice) to each agent involved in the care process: nurses, case managers, and specialists. Computer-generated feedback is provided via SMS or email to patient and caregiver and educational messages are automatically sent to patients. Frequency of feedback not specified.	• Experimental studies (RCT): n = 106 • Two conditions: 1. Intervention: n = 56 (subset randomized patients not reported) 2. Control (usual care): n = 50 (subset randomized not reported) • Randomization method not described; no details about comparability of group (except same clinical treatment)	a) Decreased HbA_{1c} in (I: 8.31 to 7.59, $P < .05$; C: 8.86 to 7.95, $P < .05$ after 6 months). NSD between groups. Patients randomized decreased HbA_{1c} (I: 8.24 to 7.44, $P < .05$; C: 8.83 to 7.78, $P < .05$, after 6 months). NSD.
[15] • Germany • 2002 • 4-8 months, follow-up unknown	Secondary care. Blood glucose meter to send clinical data via modem and telephone line to physician in diabetes center. Personal feedback for proper dose adjustment by diabetes specialist via telephone advice. Frequency of feedback not specified.	• Experimental studies (RCT): n = 43 • Two conditions: 1. Intervention: n = 27 2. Control (usual care): n = 16 • Randomization by lots (2:1 in favor of telecare). • Fairly good matching of groups	a) Decreased HbA_{1c} (I: 8.3 to 6.9 after 4 months, n = 27; to 7.1 after 8 months, n = 11; C: 8.0 to 7.0 after 4 months, n = 16, to 6.8 after 8 months, n = 10). NSD between groups. e) System appeared easy to use; patients' feeling of security increased through availability of BG data and the possibility of consulting a caregiver within minimal time, without the need to travel to the diabetes center. f) Cost and time savings in I (saving in consultation time although intensified contacts with caregiver); on caregiver's side patient's time significantly increased.
[16] • Netherlands • 1999 • 12 months, follow-up unknown	Primary/secondary care. Electronic communication network linking the physicians' computer-based patient records (GPs and interns in hospital) to enable electronic data interchange. System provides computer-generated prompts for physicians to deliver feedback (messages). Frequency of feedback not specified.	• Quasi-experimental studies: n = 275 • Two conditions: 1. Intervention: n = 215 2. Control (usual care): n = 60 • Intervention group consisted of patients from GPs with highest number of referred patients. Average age in intervention group higher; fewer type 1 patients than control group -Nonstandardized questionnaire	a) Decreased HbA_{1c} (I: 7.0 to 6.8, $P <$ .05; C: 6.6 to 6.5, $P = .52$). NSD between groups. c) Increased frequency of patient-caregiver communication ($P < .01$); more complete information about patient care in I than in C.

Reference, Country, Year, and Duration of Intervention	Care Setting and Intervention	Study Design	Reported Findings (Improvements) *
[17] • United States • 2002 • 12 months, follow-up unknown	Secondary care. Health Hero iCare Desktop and Health Buddy appliance for daily monitoring of clinical data and educational reinforcement by case manager (profession not specified) in medical center. System prompts to action if indicated by daily values. Personal feedback by telephone in case of alarming values.	• Controlled observational studies (cohort studies): n = 338 • Two conditions: 1. Intervention: n = 169 2. Control: n = 169 (cohort) • Cohort representative of the general population in terms of ethnicity	b) Mean improvement in mental component (SF-12) after 6 months in I (*P* < .0264) and in physical component after 6 months (*P* < .0518). c) Increased satisfaction regarding communication with caregivers in I (from 88% of patients after 3 months to 95% at 1 year). d) Better understanding of their medical condition (93% of patients), better able to manage their disease (93% of patients) after 1 year. e) Ease of use increased over time (75% of patients after 3 months to 88% after 1 year). f) Reduction of overall utilization and charges after 1 year; in I overall charges of US $747 per patient per year; inpatient admissions reduced 32% (*P* < .07); emergency room encounters reduced 34% (*P* < .06); post-discharge care visits reduced 44% (*P* < .028); outpatient visits reduced 49% (*P* < .001).
[18] • Denmark • 2006 • 6 months, follow-up unknown	Integrated care. Website for transmission of blood glucose data entered by patient and reviewed by diabetes team (2 diabetic nurses, 1 consultant doctor, 1 medical secretary, and 1 dietitian) and personal feedback by diabetes team by email about diabetes regimen. Frequency of feedback not specified. Based on theory of patient-centeredness and the Bayesian model of carbohydrate metabolism.	• Observational studies without control group (case series): n = 13 • Three conditions: 1. Patients: n = 3 2. Health care professionals: n = 5 3. Health care professionals: n = 5 (focus group)	c) Patients experienced greater confidence and a more personal report with staff after 6 months using the system. Email facilitated a dialogue between patient and diabetes team. d) Improved self-control (patients checked blood glucose more often); increased awareness of blood sugar regulations. e) DiasNet caused changes in tasks and duties of the diabetes team (required enhanced competence of nurse with regard to insulin dose adjustments); patients were dissatisfied with the feedback from staff.
[19] • United Kingdom • 2005 • 9 months, follow-up unknown	Secondary care. Blood glucose monitor and telephone network for transmission of data and GPRS mobile phone to send data (daily) to diabetes nurse specialist in clinic. Real-time graphical phone-based feedback for the previous 2 weeks together with nurse-initiated support using a Web-based graphical analysis of glucose self-monitoring results and personal feedback by phone in case of concerns. Frequency of feedback not specified. Based on theory of patient-centeredness.	• Experimental studies (RCT): n = 93 • Two conditions: 1. Intervention: n = 47 (Web-based graphical analysis, nurse initiated support) 2. Control (real-time graphical phone-based): n = 46 • Randomization (computer program); gender and psychiatric scores evenly distributed between the randomized groups	a) Decreased HbA_{1c} (I: 9.2 to 8.6 after 9 months, *P* < .001; C: 9.3 to 8.9 after 9 months, *P* < .05). NSD between groups. e) Difference in proportion of transmitted blood glucose results (40% more in I than in C, *P* < .0001).
[20] • Spain • 2004 • 9 months, follow-up unknown	Care setting not specified. PC, Web browser, or a cell phone with Wireless Application Protocol for transmission of clinical data. Automatic generated responses and personal feedback by physicians (not specified whether GPs or specialists in hospital) that could be read during patient's next online session. Frequency of feedback not specified.	• Observational studies without control group (case series): n = 172 • Two conditions: 1. Case study: n = 12 2. Questionnaire: n = 160 (135 non-diabetic students, 25 diabetic patients)	d) Patients were satisfied with the continuity and self-efficacy of care; lack of time was a drawback for 38%; 75% expressed a preference for sending data via a cellular phone (SMS). e) Patients used the system every 2.0 days (SD 2.1), and doctors reviewed patient data every 4.0 days (SD 3.9); the average number of visits to the website was 477 per month.

Reference, Country, Year, and Duration of Intervention	Care Setting and Intervention	Study Design	Reported Findings (Improvements) *
[21] • Spain • 2004 • 8 months, follow-up unknown	Care setting not specified. Patients send blood glucose levels and body weight to a server by SMS. Automatic server answers SMS each time data were sent. Monthly hemoglobin results automatically sent to physicians (not specified whether GPs or specialists in hospital). Physicians can send messages to patients if necessary.	• Observational studies without control group (case series): n = 23 • One condition	e) SMS provided a simple, fast, efficient, and low-cost adjunct to the medical management of diabetes at a distance. Particularly useful for age groups (elderly, teenagers) that are known to have difficulty in controlling diabetes well. f) Total of 25 messages per month; €3.75 per month per patient.
[22] • France • 2006 • 6 months, follow-up unknown	Secondary care. Clinical data from patients' glucose meters are downloaded every 2 weeks to pharmacists' PC. Reinforced follow-up via fax mediated by the local pharmacist in contact with the specialist in the hospital (diabetologist). Diabetologist sends instruction to family by email or phone within 5 days.	• Experimental studies (RCT): n = 100 • Two conditions: 1. Intervention: n = 50 2. Control (usual care): n = 50 • Randomization via computer-generated sequence using block randomization with stratification by age • Comparable intervention and control groups (age, gender, HbA_{1c}, frequency of SBGM, type of insulin therapy program)	a) Decreased HbA_{1c} (I: 9.3 to 9.27, P = .59; C: 9.2 to 9.12, P = .58). NSD between groups. c) Caregivers' response to faxes was 81% (at 3 months); decreased to 50% (6 months). d) Frequency of self blood glucose monitoring per day did not differ between groups at the end of the study (P = .53). e) Only 32% of faxes (out of 100% expected) from family homes were received due to technical problems.
[23] • Spain • 2002 • 12 months, follow-up expected	Secondary care. Clinical data from a blood glucose meter are sent (automatically or manually) from a patient unit to the medical workstation for physicians (diabetologist in hospital). System offers tools to collect, manage, view, and interpret data and to exchange data and messages. Physicians personally answer patients' questions within 24 hours via system. Frequency of feedback not specified.	• Quasi-experimental studies: n = 10 • Two conditions: 1. Intervention: n = 5 2. Control: n = 5 (cross-over design, switch half way through the trial) • Both groups comparable concerning intervention time and inclusion criteria (inadequate metabolic control, DM duration greater than 5 years)	a) Decreased HbA_{1c} (I: 8.4 to 7.9, P = .053); increased in C (8.10 to 8.15, P = .58). NSD between groups. c) Patients transmitted 3524 blood glucose readings, 1649 daily insulin adjustments, 24 exercise reports, and 10 diet modifications. Electronic communication with caregivers was limited; a total of 63 text messages were sent by all patients. Caregivers sent 118 text messages to patients (feedback and therapy modifications). Caregivers performed more therapy changes in I than in C due to the ability to assess patient's condition on a frequent basis. d) Increased confidence in daily self-management. e) Patients found the system has high utility despite several technical problems.
[24] • United States • 2002 • 3 months, follow-up unknown	Primary care. Email for communicating disease management issues between Veterans Affairs primary caregiver and pharmacists. Personal feedback to patients via telephone by pharmacist. Frequency of feedback not specified.	• Quasi-experimental studies: n = 65 • Two conditions: 1. Intervention: n = 30 2. Control (usual care): n = 35 • Intervention: patients had a recent change made to their therapy to lower blood glucose levels • Control: remaining patients of the 65 • Comparable HbA_{1c} at baseline in two groups	a) Decreased HbA_{1c} (I: 10.0 to 8.2; P < .001; C: 10.2 to 8.6, P < .001). NSD between groups. f) Email communication reduced the number of face-to-face and telephone consultations between caregivers. g) Clinical recommendations for altering diabetes care sent via email to primary caregiver resulted in a significant reduction in HbA_{1c} in I.
[25] • Spain • 2006 • 12 months, follow-up unknown			

Reference, Country, Year, and Duration of Intervention	Care Setting and Intervention	Study Design	Reported Findings (Improvements) *
	Secondary care. Data from glucose meter and vocal messages concerning insulin doses and events are sent via modem (twice a week) to diabetes team (in hospital, members of diabetes team not specified). Diabetes team provides personal feedback. No details provided about form and frequency of feedback.	• Experimental studies (RCT): n = 30 • Two conditions: 1. Intervention: n = 18 2. Control (usual care): n = 15 • Randomization via random variable generator; baseline data (HbA_{1c}, BMI, weight, insulin, DM) and characteristics (age, gender, daily activities) comparable in two groups	a) Decreased HbA_{1c} (I: 8.4 to 7.6; C: 8.9 to 7.6, after 12 months); NSD between groups. b) General health status did not change in groups (SF-12); quality of life improved in I (NS) and C ($P < .05$); significant increase in knowledge in I ($P < .05$) and C ($P < .05$). d) 80% of patients reported that appointments in I did not interfere with daily life; 100% of patients in C reported daily interference with outpatient appointments. f) Time and costs saved by patients. Costs were lower (length of appointment 0.25 h in I versus 0.5 h in C). But 30% of the diabetes team and patient appointments were longer than expected due to technical problems (0.25 h versus 1 h).
[26] • South Korea • 2006 • 12 weeks, follow-up unknown	Tertiary care. Clinical data are entered daily in system via website or cellular phone (SMS). Automatic feedback (reminder) is generated in case patient has not forwarded data for more than a week. Personal feedback provided weekly by nurse in tertiary care hospital via SMS, telephone, or Internet.	• Observational studies without control group (before-and-after design): n = 42 • One condition	a) Patients had a mean decrease of 28.6 mg/dL in fasting plasma glucose (P= .006) and 78.4 mg/dL in 2-hour postprandial blood sugar levels (P= .003). d) Mean increase in care satisfaction score in I (68.6 to 79.5,P= .03).
[27] • Italy • 2006 • 56 weeks, follow-up unknown	Care setting not specified. Blood glucose data from a glucose meter are sent via Internet or telephone to the system. Data are automatically analyzed in order to detect metabolic alterations and, if necessary, generate alarms. If necessary, physician (not specified whether GP or specialist in hospital) responds and a message is automatically sent to patient by email or SMS. Frequency of feedback not specified. Based on a general model for the coordination of care (Chronic Care Model).	• Experimental studies (RCT): n = 56 • Two conditions: 1. Intervention: n = 30 2. Control (usual care): n = 26 • No randomization details; both groups comparable (age, treatment)	a) Location 1 decreased HbA_{1c} (I: 8.52 to 8.30, $P < .05$; C: 8.97 to 8.82). NSD between groups. Location 2 decreased HbA_{1c} (I: 8.40 to 7.75; C: 10.15 to 9.28, after 12 months). NSD between groups. c) Patients transferred 20000 BGL readings and 2000 insulin doses (56 weeks, over 2 locations); the frequency of service usage and quantity of data collected were considered satisfactory. e) Overall usability perception was high (TSQ), especially in adult patients.
[28] • United States • 2005 • At least 24 months, follow-up unknown	Primary care setting. Blood glucose data from glucose meters sent to the diabetes team weekly (team composition not specified) and nurses of the children's medical care service clinic. Feedback is provided during a clinical, face-to-face session. Online education for school personnel, families, and caregivers is provided on a website. No details provided about form and frequency of feedback.	• Observational studies without control group (case series): n = 74 • Four conditions: 1. Patients: n = 44 2. Caregivers: n = 6 3. Case managers: n = 6 4. School nurses: n = 18	c) Improved patient-caregiver communication for patients in a remote area. Use of website by nurses increased substantially when it was approved for 3 contact hours of continuing education. d) 40% of patients completed educational modules on the website. e) Users (patients, family, and school nurses) expressed satisfaction with the technology. g) Compliance with school health plans improved compared with baseline.
[29] • Australia • 2002 • 6 weeks, no follow-up	Care setting not specified. Internet-based diabetes management systems (myDiabetes, LifeMasters) for evaluation of diabetes management. No details about form and frequency of feedback. Based on the push-pull model for retrieving and seeking information.	• Expert opinion based on consensus: n = 5 (1 caregiver, 3 diabetic patients, 1 expert) • One condition	

Reference, Country, Year, and Duration of Intervention	Care Setting and Intervention	Study Design	Reported Findings (Improvements) *
			e) LifeMasters appeared successful in integrating the health care provider in diabetes management; myDiabetes is effective in providing a communication channel for community creation. LifeMasters appeared a more complete system than myDiabetes (monitoring, personalization, communication, information, technology).
[30] • United States • 3 months, follow-up unknown	Primary care. Internet-based, diabetes self-management and peer support intervention (chat room). The Diabetes Network was designed to complement medical treatment by providing personalized lifestyle interventions and social support via an Internet-based program accessible from patients' home. Simplified computers and training were used. Intervention included online blood glucose tracking, twice weekly patient-physician (primary care provider) contact (questions), and message postings on forum (real time chat discussion). Personal dietary advice by primary care provider via website, forum.	• Experimental studies (RCT): n = 133 • Four conditions: 1. Information only group: n = 33 2. Peer support group: n = 30 3. Personal self-management coach condition: n = 37 4. Combined condition of the three above: n = 33 • Randomization by presence or absence of each of the components (peer support, personalized self-management); groups comparable (gender, education, age, years diagnosed)	a) Decreased HbA_{1c} in PSMCC (I: 7.75 to 7.73), in PSC (I: 7.64 to 7.59), in CC (I: 7.46 to 7.28). HbA_{1c} increased in C (7.20 to 7.37 after 3 months) Overall improvement in dietary behavior (reduction of fat intake, improved dietary practices) in 4 conditions, but no significant between-condition differences. b) Slight improvements in quality of life (psychological well-being SF-12) in 4 conditions, especially for PSMCC and CC. c) Two support conditions (PSC, CC) generated significantly more log-ons (M = 61 and 70, respectively, for PSC and CC; M = 40 (PSMCC); M = 25 in IOC; $P < .02$).
[31] • United States • 2005 • 12 months, follow-up unknown	Primary care. Clinical data from glucose meters are sent three times a week via Internet to a website. Web-based care management group received a notebook, glucose and blood pressure monitoring devices, and access to a care management website. The site provides educational modules, accepting uploads from monitoring devices and an internal messaging system for patients to communicate with the care manager. Automatic feedback is provided if patients have not forwarded data in 2 weeks. Care manager contacts patients by phone; diabetes nurse communicates with patients about education using the internal messaging system. The care manager responded to queries within 1 working day during office hours.	• Experimental studies (RCT): n = 104 • Two conditions: 1. Intervention: n = 52 2. Control (usual care): n = 52 • No randomization details; both groups comparable (age, gender, education, metabolic values)	a) Significant decrease in HbA_{1c} in I and C ($P < .001$). A greater decline over time (12 months) in I (10.0, −1.6%) and C (9.9, −1.2%, $P < .05$). Individuals who persisted with website usage (at least one website log-in every 3 months, $P < .05$) had a greater improvement in HbA_{1c} than usual care. HDL cholesterol rose and triglycerides fell in the Web-based group ($P < .05$). d) Regular data uploads ($P < .02$) were more likely to achieve and maintain reductions in HbA_{1c}.
[32] • United States • 2004 • 3 months, follow-up unknown	Primary care. Web-based disease management program based on an interactive electronic medical record and secure email system. System contains My Upload Meter to automatically upload clinical data daily sent and Diabetes Daily Diary educational website. Automatically generated clinical reminder, email response every weekday (by nurse practitioner in primary care internal medicine clinic). Based on a general model for the coordination of care such as the Chronic Care Model.	• Observational studies without control group (before-and-after design): n = 9 • One condition	c) If expectations were not met, participants felt their concerns were less valued, and they felt more isolated from their caregiver. d) Participants felt safer having real-time access to their personal health information. They felt more able to manage diabetes by means of seeing laboratory results in the live record at home. e) Frustration with unmet expectations when program did not work as expected (technical failures).

Reference, Country, Year, and Duration of Intervention	Care Setting and Intervention	Study Design	Reported Findings (Improvements) *
[33] • Netherlands • 2001 • duration not specified, follow-up unknown	Primary/secondary care. Shared-care project whereby all examinations, which take place every 3 months and are performed by the GP, follow standardized procedures. Results are emailed to the diabetologist and laboratory results are automatically sent to both GP and diabetologist. Feedback by post mail from diabetologist to GP.	• Observational studies without control group (case series): n = 594 • Three conditions: 1. Patients treated in project: n = 336 2. Patients treated by GP: n = 225 3. Patients treated in outpatient clinic: n = 33	a) Decreased HbA_{1c} in UDP (7.8 to 6.8, $P < .0001$); mean inclusion duration 3.2 years. Lipid profiles improved in I: plasma cholesterol decreased (6.1 to 5.9, $P < .0001$), plasma triglyceride decreased (1.9 to 1.7, $P < .0001$), and diastolic blood pressure decreased (86 to 83, $P < .001$). d) Data records of UDP cohort were most complete compared to other groups. e) GPs intended to continue participating in UDP despite shared care taking more time. g) Standardized data transfer (protocol driven) between GP, diabetologist, and laboratory established an effective infrastructure for shared diabetes care.
[34] • China • 2001 • 12 weeks, follow-up unknown	Secondary care. Dietary and clinical data are recorded in hand-held computer and sent twice a week via a modem to the diabetes team of a hospital diabetes clinic (composition of diabetes team not specified). System generates automatic feedback about content of food.	• Quasi-experimental studies: n = 19 • Two conditions: 1. Intervention: n = 10 2. Control: n = 9 • Each group used the DMS for 3 months; served as the control group for another 3 months (cross-over design); comparable groups	a) Decreased HbA_{1c} (I: 8.56 to 7.55 after treatment, to 7.84 at end of 12-week project; C: 8.81 to 8.76 after treatment, to 8.40 after end of 12-week project). Mean difference was 0.825 ($P < .019$, n = 19). e) The DMS was acceptable; 95% found it easy to use, and 63% found it useful.

* a) clinical values, b) quality of life, c) interaction, d) self-care, e) usability of technology, f) cost reduction, g) transparency of guidelines, h) equity (availability of health care to everyone)

BG, blood glucose; BGL, blood glucose levels; BMI, body mass index; C, control group; CC, combined condition; DM, diabetes mellitus; DMS, diabetes monitoring system; GP, general practitioner; I, intervention; IOC, information only condition; M, mean; NS, not statistically significant; NSD; not statistically significant difference, PSC, peer support condition; PSMCC, personalized self-management coach condition; SBGM, self blood glucose monitoring; SMS, Short Message Service; TSQ, Telemedicine Satisfaction Questionnaire; UDP, Utrecht Diabetes Project; WHO, World Health Organization

Table 4. Overview of videoconferencing and combined interventions

Reference, Country, Year, and Duration of Intervention	Care Setting and Intervention	Study Design, Inclusion Criteria, and Data Gathering Methods	Reported Findings (Improvements)
[35] • Austria • 2002 • 12 months, follow-up unknown	Primary/secondary care. Patient and GP consult specialist in diabetes center via PC fitted with videoconferencing card connected to a single ISDN line. Personal feedback (diabetologist) on therapy change during video session. Based on organizational learning theory.	• Observational studies without control group (before-and-after study): n = 154 • One condition	a) Decreased HbA_{1c} (8.1 to 7.8, $P < .05$, after 12 months); systolic blood pressure (156.0 to 148.0 mmHg, $P < .0005$); diastolic blood pressure (88.0 to 83.0 mmHg, $P < .0005$). GPs measured late complications and metabolic parameters more frequently during the project than they did before. e) Technical quality of therapeutic counseling via videoconferencing was sufficient, good enough to evaluate the clinical course of foot ulcer; duration of interview via videoconferencing with patients was on average 12 min (range 4-23 min). f) Reduction of hospital admissions from 12 before I to 7 (during 1 year); duration of hospitalization for whole patient group for treatment of acute complications was reduced (110 to 68 days per year).
[36] • China • 2005 • 8 weeks, no follow-up	Secondary care. Patients in a community center and specialist in hospital connected via a large-screen television in the center and a digital camera for better visualization of skin and wound condition and Internet protocol networking videoconferencing units with televisions. Educational sessions (caregiver not specified) regarding diet and ideal body weight, foot care, glucose monitoring, and exercise prescription. No details provided about form and frequency of feedback. Based on a model of service delivery using the group setting for education regarding disease management of elderly people with diabetes.	• Observational studies without control group (before-and-after study): n = 22 • One condition	a) Reduction in total calorie intake (energy: $P= .000$; carbohydrates: $P < .002$; protein: $P < .039$; fat: $P < .001$) and BMI ($P < .005$). b) Improvement in disease-specific and generic measures of quality of life (SF-36, physical: $P= .000$; general health: $P < .001$; vitality: $P < .005$; social: $P < .013$; emotional: $P < .019$; DQOL: $P= .000$). d) Improved disease knowledge (mean score 7.91 to 13.05); better diabetes control (measured by 2-hr hemastix). c/e) Patients accepted videoconferencing, preferred face-to-face interaction; staff found system easy to use.
[37] • Norway • 2005 • duration not specified, follow-up unknown	Secondary care. Treatment of diabetic foot ulcers whereby a nurse goes to the patient's house with videophone and laptop and consults physician (specialist in hospital). An online ulcer record system is available capable of notifying the physician by SMS messages. Feedback from physician via videophone.	• Observational studies without control group (case series): n = 20 • Two conditions: 1. Workshops: n = 15 2. Pilot test: n = 5	e) Staff and patients found equipment easy to use. f) Patients saved time (no travel to hospital, no waiting time). g) Shared documentation enhanced treatment (coordination).
[38] • United States • 2001 • 24 months, follow-up unknown	Primary care. Video visits in addition to skilled nursing visits (Visiting Nurse Association). Patient station in the home has camera with close-up lens. Patient and clinical station linked together over ordinary telephone lines via standard modem. No details provided about form and frequency of feedback.	• Experimental studies (RCT): n = 171 • Two conditions: 1. Intervention (1 video visit, 1 home visit, 1 video visit): n = 86 2. Control (skilled nursing home visits only): n = 85 • No randomization details; groups comparable (gender, average age, mean diabetes severity score, mean number of comorbidities)	f) Cost savings without compromising quality; videoconferencing has the potential to provide the same number of patient encounters at lower costs; financial benefit increases as the duration of the patient care episode increases. Fewer videoconferencing patients required recertification after 60 days in I compared to C (23% versus 25.6%, $P < .001$); 63.7% of videoconferencing patients were discharged to home care compared to 39% of C group ($P < .001$). 28% of C was hospitalized during 60 days compared to 10% of videoconferencing patients ($P < .05$).

Reference, Country, Year, and Duration of Intervention	Care Setting and Intervention	Study Design, Inclusion Criteria, and Data Gathering Methods	Reported Findings (Improvements)
[39] • United States • 2003 • 3 months, in case of success, follow-up	Secondary care. Patients report blood sugar levels, injections, and food intake daily either by telephone, videophone (analogue videophone connected to a television), or email. Psychological staff provides advice on changing and maintaining behavior (phone, videophone, or email). Diabetes nurse ensures medical needs.	• Observational studies without control group (case series): n = 5 • Three conditions: 1. Telephone intervention: n = 3 2. Videophone intervention: n = 1 3. Email intervention: n = 1	a) Decrease of HbA_{1c} (for each child: from 9.7 to 8.5; from 8.7 to 7.1; from 13 to 6.1, from 10.2 to 9.4; from 10.9 to 7.9, after 3 months). d) Better self-control (managing the sending of blood sugar); no hospitalizations; no school absences.
[40] • Canada • 2002 • 3 months, follow-up unknown	Secondary care. Video visits whereby patient at home communicates with physician in hospital. Equipment not specified. No details provided about form and frequency of feedback. Based on Donabedian's principle of quality of care.	• Observational studies without control group (case series): n = 25 • Four conditions: 1. Patient group: n = 8 2. Nurse group: n = 13 3. Physicians: n = 7 4. Managers: n = 7	e) Patients and managers identified a higher degree of readiness for videoconferencing in patients because of the potential to support independence in their homes and in managers because of efficiency of the system. Patients wanted to maintain their level of health but with minimum intrusiveness; caregivers were more interested in measurable clinical outcomes (blood pressure, glucose); managers focused on cost-effectiveness.
[41] • United States • 2003 • 3 months, follow-up unknown	Primary care. Patients at remote telemedicine site connected to nurse educator and dietitian in diabetes center through videoconferencing. Both sites equipped with PC, digital camera, and a conference system. Three one-on-one monthly educational sessions (nurse and educator). Feedback given by nurse educator and dietitian during sessions.	• Experimental studies (RCT): n = 46 • Two conditions: 1. Intervention: n = 24 2. Control (education in person): n = 22 • Randomization via random permuted blocks; groups comparable (age, gender, BMI, duration of diabetes)	a) Decrease in HbA_{1c} (I: 8.7 to 7.8, $P < .001$; C: 8.6 to 7.6, $P < .001$, after 3 months). NSD between groups. b) Reduced diabetes-related stress was observed in I and C ($P < .007$). NSD between groups. d) More positive appraisal of their diabetes ($P < .05$) in both groups. e) Most patients who received videoconferencing felt comfortable with videoconferencing and found it very convenient; overall satisfaction was high (score 4.3/5). Satisfaction with treatment increased in both groups ($P < .001$). NSD between groups.
[42] • United States • 2005 • at least 24 months, follow-up unknown	Secondary care. Nurse and patient in clinic consult physician in hospital via videoconferencing equipment and hand camera, semimonthly. An educational website covers the basics of diabetes care. No details provided about form and frequency of feedback.	• Observational studies without control group (before-and-after study): n = 44 • One condition	e) Over 90% of patients and family members expressed satisfaction with videoconferencing. f) Reduced hospitalizations (before I, on average 13 per year [47 days]; after I, 3.5 per year [5.5 days]). Reduced emergency department visits (from 8 to 2.5 per year). The visit interval decreased from 149 to 89 days as the bi-weekly telemedicine clinics replaced quarterly clinics. h) Improved access to specialized health care via videoconferencing (underserved area), in combination with online education improved health status.
[43] • Australia • 2003 • 28 months, follow-up unknown		• Observational studies without control group (case series): n = 170 • Three conditions: 1. Routine consultation: n = 135 2. Complication consultations with 1 patient: n = 25 3. Education sessions: n = 10	f) Reduced travel time for specialist hospital staff (by conducting clinics via videoconferencing), while maintaining patient contact. h) Improved access to specialist services (telepediatric) from rural and remote areas.

Reference, Country, Year, and Duration of Intervention	Care Setting and Intervention	Study Design, Inclusion Criteria, and Data Gathering Methods	Reported Findings (Improvements)
	Secondary care. Video consultation between patient (groups) at regional center and pediatric specialist in hospital used in three ways: (1) routine specialist clinics via videoconference using PC with videoconferencing equipment, digital camera, and ISDN line, (2) ad hoc patient consultations at time of urgent clinical need, and (3) education to staff and patients throughout the state of Queensland. Personal feedback by specialist in hospital to patient and staff during video session. Frequency of feedback not specified.		
[44] • United States • 2000 • 3 months, follow-up unknown	Primary care. Monitoring metabolic values and dietary behavior from patients' home unit to primary care clinic, family practice, or internal medicine at the medical center. Weekly patient-nurse consultation through videophone over a telephone line to discuss metabolic values and dietary behavior. Email contact maintained between case manager, specialist, and the family practitioner. Nurse case manager provides advice once a week during session; primary care physician is contacted once a month (for advice).	• Experimental studies (RCT): n = 28 • Two conditions: 1. Intervention: n = 15 2. Control (no information available about control group): n = 13 • Randomization (stratified based on age, gender, microalbumin, creatinine, HbA_{1c}) • Comparable groups	a) Decreased HbA_{1c} (I: 9.5 to 8.2, $P < .05$; C: 9.5 to 8.6, after 3 months). NSD between groups. Mean weight reduction (4%).
[45] • United States • 2004 • 12 months, follow-up unknown	Secondary care. Self-management therapy video consultation (on nutrition) between patient at home and specialist in hospital. The telediabetes program had been in operation for 10 years. Equipment used not specified. Registered nurse conducts educational session with patient by videoconferencing.	• Observational studies without control group (case series): n = 60 • One condition	c) Sustainability of the telediabetes program depends on a feedback system; the effectiveness of the process depends on an interactive ongoing collaboration between patient and caregiver. f) Reduced travel time for patients and caregivers. g) Administration took a long-term view of the value of telemedicine service; service delivery followed national diabetes standards and a well-defined cycle of care within a long-term quality improvement program and consistent education program resulted in sustainable diabetes care. h) The system provided access to specialized health care in remote areas.
[46] • United States • 2004 • 12 weeks, follow-up unknown	Secondary care. Physician and physical therapist in hospital connected with patient and nurse in medical center for the treatment of diabetic foot ulcers. Both equipped with a videoconferencing unit and a television monitor. The hospital has a hand-held camera for real-time transmission of close-up images of the foot and a document camera for real-time transmission of foot x-ray images. Personal feedback by nurse during weekly session.	• Quasi-experimental studies: n = 140 • Two conditions: 1. Intervention: n = 20 2. Control (face-to-face foot program): n = 12 • Comparable groups (age, wound condition)	a) No difference in I and C in the average forefoot ulcer healing time, the percentage of ulcers healed in 12 weeks, or the adjusted healing time ratio. e) Equipment appeared easy to use and provided clear viewing of foot lesions and x-rays. Patients appeared well satisfied with use of technology. f) Patients saved travel time. h) Patients appreciated the convenience of being treated at their local facility (had more access to specialized care).
[47] • China • 2002 • 18 weeks, follow-up unknown		• Observational studies without control group (case series): n = 41 • One condition	

Reference, Country, Year, and Duration of Intervention	Care Setting and Intervention	Study Design, Inclusion Criteria, and Data Gathering Methods	Reported Findings (Improvements)
	Primary care. Education in small patient groups in health center given by nurse in diabetic center through videoconferencing equipment connected by a local area network. Four sessions, each lasting 2 hours. Personal feedback (from diabetes nurse) during sessions.		c) Videoconferencing enabled community nurses in primary care to link with nurse specialist in diabetes center to provide diabetes education in small groups. d) Diabetes education conducted via videoconferencing was highly acceptable (mean total score [TSQ] was 61.9/75). e) Significant positive correlation between age and satisfaction (r = 0.39); the older the patient, the higher the level of satisfaction with videoconferencing and with caregiver; no relationship between satisfaction with videoconferencing and baseline HbA_{1c}. Lack of a perceived need to have assistance while using equipment and the perceived ability of videoconferencing to meet health care needs were most important predictors of satisfaction (accounted for 82% of the variance in satisfaction). f) Patients saved travel time and waiting time.
[48] • United States • 2005 • 24 months, follow-up unknown	Primary care. Intervention consists of three parts: 1. Hand-held in-home messaging device (Health Buddy) with disease management dialogues: Patients answer a daily series of questions and the care coordination staff of Veterans Health Administration (staff composition not specified) review responses daily to determine the level of risk for health care emergencies. 2. Telemonitoring with two-way audio-video connectivity that allowed for weekly monitoring of glucose and vital signs. 3. Videophone with two-way audio-video connectivity, not including biometric monitoring. Patients followed up on a weekly basis for biometric info. Care coordinator reviews data daily to determine risks. Based on Wagner's Chronic Care Model.	• Observational studies without control group (before-and-after study): n = 445 • One condition	b) Significant improvement in health-related quality of life during 1 year (role-physical functioning: $P = .02$; bodily pain: $P = .005$; social functioning [SF-36]: $P < .05$). e) Patients found equipment easy to use (> 95% of patients). f) Reduction in proportion of patients who were hospitalized (50% reduction, $P < .0001$), in emergency room visits (11% reduction, $P < .04$), in average number of bed days of care (decreased an average of 3.0 days, $P < .0001$). Patients were 35% more likely to have had one or more need-based primary care clinic visits ($P = .0004$).
[49] • United States • 2005 • 24 months, follow-up unknown	Primary care. See [48]. Comparison of weekly monitoring with care coordinator versus daily monitoring with home message system. Personal feedback if necessary: caregiver calls patient or facilitates an appointment. Instant camera with grid film for following diabetic wounds for aggressive wound management (weekly monitored group targeted patients with active diabetic wounds). Patient takes two pictures of wounds and mails them to care coordinator. Care coordinator reviews data daily to determine risks. The daily monitored group consists of diabetics who had wounds that required careful monitoring.	• Quasi-experimental studies: n = 297 • Two conditions (two different monitoring intensities): 1. Weekly monitoring, intensively monitored: n = 197 2. Daily monitoring, less intensively: n = 100 • In weekly monitored group, patients were younger; in daily program, more patients were married; both groups comparable in clinical and sociodemographic characteristics	

Reference, Country, Year, and Duration of Intervention	Care Setting and Intervention	Study Design, Inclusion Criteria, and Data Gathering Methods	Reported Findings (Improvements)
			a) Decreased HbA_{1c} in I (weekly monitoring, from 8.3 to 8.1,*P*= .22) and in C (daily monitoring, from 8.7 to 8.8,*P*= .78) after 24 months. NSD between groups. Adjusted mean values HbA_{1c} in I (weekly monitoring) from 8.1 to 7.8 (*P*= .20) and in C (daily monitoring) from 8.6 to 8.7 (*P*= .79) after 24 months. NSD between groups. f) Proportion of one or more hospital admissions decreased in daily monitoring group (77 to 43, *P* < .01) and increased in the weekly monitoring group (73 to 106, *P* < .01). The change in the average number of hospital bed days was 8 days lower in daily monitored group than in the weekly monitored group (*P* < .0001). Unscheduled primary care clinic visits were lower in the daily monitoring group (67 to 16) than in the weekly monitoring group (108 to 116); significant difference between the two groups (*P* < .01).
[50] • United States • 2005 • 12 months, follow-up unknown	Primary care. Patient-centered care coordination / home telehealth program based on Wagner's Chronic Care Model provides self-management and decision support via electronic reminders and care coordinator. The system used an in-home dialogue box (via patients' cell phone) to answer questions about health status. Answers were sent daily over the Internet to care coordinator who responded in case of alarming values. A two-way audio video connectivity and videophone were also used (see [48]).	• Controlled observational studies (cohort studies): n = 800 • Two conditions: 1. Intervention: n = 400 2. Control (no intervention): n = 400 • Propensity scores were used to improve the match between I and C. • A difference-in-differences approach used to measure the effects of the intervention on service use	f) Significant difference between I and C in need-based primary care visits, increasing in I (7.6%) and decreasing in C (12%) (*P* < .01). The likelihood of 1 or more emergency department visits decreased in I and C (significant differences between groups, *P* < .0001). I group had a lower relative likelihood of having 1 or more hospitalizations than patients in the control group (control for HbA_{1c}, NS difference between I and C). h) Increase in access to care in I.
[51] • United States • 2005 • 5 months, follow-up unknown	Primary care. Monitoring blood glucose via a home telemedicine unit coupled with care management delivered from the diabetes centers at two hospital-based hubs. Patients can upload monitoring data, send secure email, access an educational website, and use two-way video / voice conferencing. No details provided about form and frequency of feedback.	• Observational studies without control group (case series): n = 5 • One condition	e) Technology-related problems (telecommunication, connectivity) were the primary cause of installation difficulties (in patients' homes). Patient education and training are the most critical success factors. Patient education and training accounted for two thirds of the in-home time for installation of equipment. Nurse installers are patient-centric rather than technology-centric.

[*] a) clinical values, b) quality of life, c) interaction, d) self-care, e) usability of technology, f) cost reduction, g) transparency of guidelines, h) equity (availability of health care to everyone)

BMI, body mass index; C, control group; DM, diabetes mellitus; I, intervention; NS, statistically not significant; NSD, not statistically significant difference; TSQ, Telemedicine Satisfaction Questionnaire

Studies on the Effects of Teleconsultation

Settings and Interventions

Interventions took place in secondary care settings [13,15,17,19,22,23,25,34] and in primary care [24,28,30-32] (see Table 3). To improve the reliability of monitoring, clinical data such as HbA_{1c} and insulin dose were usually sent and analyzed automatically (18/22 studies). In most settings, glucose meters, palmtops, and/or cell phones were used to send data (n = 15). To enhance disease control, feedback was given via computer-generated reminders whenever values were alarming [13,14,20,21,26,27,32]. In some cases, caregivers provided personal feedback to instruct patients in case of alarming values [15,17,22,24,25,30,33,34].

Inclusion of patients in the intervention groups included such criteria as being diagnosed with type 1 [13,15,18,19,22,23,25,28] or type 2 diabetes [24,26,30,32,33], being compliant with therapy [13,22,24], being motivated to take part in the intervention [14,15] having a caregiver taking part in the intervention [17,24,31,33,34], living in the region [17,21,30,32], demographics such as being younger than 30 years [19,22] and being economically disadvantaged [17,22,28,30,32], having insulin problems [15,19,25], and poor metabolic control (HbA_{1c}> 8%) [19,22-25,31]. As well, certain conditions needed to be met, such as being able to handle the technique [15,17,18,20,26,30], having followed a structured diabetes education program [15], and having access to the Internet [14,20,26] or a (cell) phone [14,17,20,21,26,30].

Though teleconsultation is generally assumed as the solution for better disease management and care coordination of diabetic patients, the preference for this kind of technology compared to other options has not been clearly stated. Teleconsultation is supposed to be cost-effective, to deliver continuous care, and to foster time-efficient communication between patients and caregivers [13,14,16,17,19,21,23,31]. Most teleconsultation interventions (n = 18) were aimed at improving clinical values, investigating usability of technology (n = 15), intensifying interaction by means of information exchange, either among caregivers or between patient and caregivers (n = 14), and enhancing self-care (n = 12).

Effects of Teleconsultation at Clinical Level

HbA_{1c} levels were measured in eight RCTs [14,15,19,22,25,27,30,31], but only six were suitable for meta-analysis. One trial studied only children [22] and was therefore not included in the meta-analyses. Another trial [14] reported that the variance of HbA_{1c} values was significantly lower in the experimental group compared to the control group. This study was excluded because using an imputation technique was unadvisable as data provided by the author differed from the published data. Changes in HbA_{1c} values were calculated from baseline and follow-up means and standard deviations. The Jadad quality score of the trials was either 2 or 3 (Table 5).

Table 5. Randomized controlled trials with HbA_{1c} data (see Multimedia Appendix for full tables containing inclusion criteria and data gathering methods)

Study	Trial Duration (months)	Intervention			Control			Quality Score [12]
		N	Baseline and Follow-Up Values ± SD	Mean Difference ± SD	N	Baseline and Follow-Up Values ± SD	Mean Difference ± SD	
Biermann [15]	4	27	8.3 ± 2.3 6.9 ± 1.3	−1.4 ± 2.0*	16	8.0 ± 2.1 7.0 ± 1.0	−1.0 ± 1.82	3
McKay (a) [30]†	3	37	7.75 ± 1.33 7.73 ± 1.42	−0.02 ± 1.38*	33	7.20 ± 1.36 7.37 ± 1.49	0.17 ± 1.43	3
McKay (b) [30]†	3	30	7.64 ± 1.71 7.59 ± 1.66	−0.06 ± 1.69*	33	7.20 ± 1.36 7.37 ± 1.49	0.17 ± 1.43	3
McKay (c) [30]†	3	33	7.46 ± 1.35 7.28 ± 1.28	−0.18 ± 1.32*	33	7.20 ± 1.36 7.37 ± 1.49	0.17 ± 1.43	3
Farmer [19]	9	47	9.2 ± 1.1 8.6 ± 1.4	−0.62 ± 2.42‡	46	9.3 ± 1.5§ 8.9 ± 1.4	−0.38 ± 2.36	2
McMahon [31]‖	12	52	10.0 ± 0.8	−1.6 ± 1.4	52	9.9 ± 0.8	−1.2 ± 1.4	2
Jansa [25]	12	18	8.4 ± 1.2 7.6 ± 0.9	−0.8 ± 0.74§	15	8.9 ± 1.3 7.6 ± 0.7	−1.3 ± 0.64	3
Larizza [27]¶	12	15	8.40 ± 2.53 7.75 ± 1.16	−0.65 ± 2.20*	14	10.15 ± 3.25 9.28 ± 2.34	−0.87 ± 2.90	2

*Imputation technique.

†Intervention (a) was personal self-management coach (n = 37), intervention (b) was peer support (n = 30), and intervention (c) was combined condition (n = 33).

‡Calculated using 95% CI.

§Calculated using *P* values provided by author.

‖Precise follow-up data were not reported.

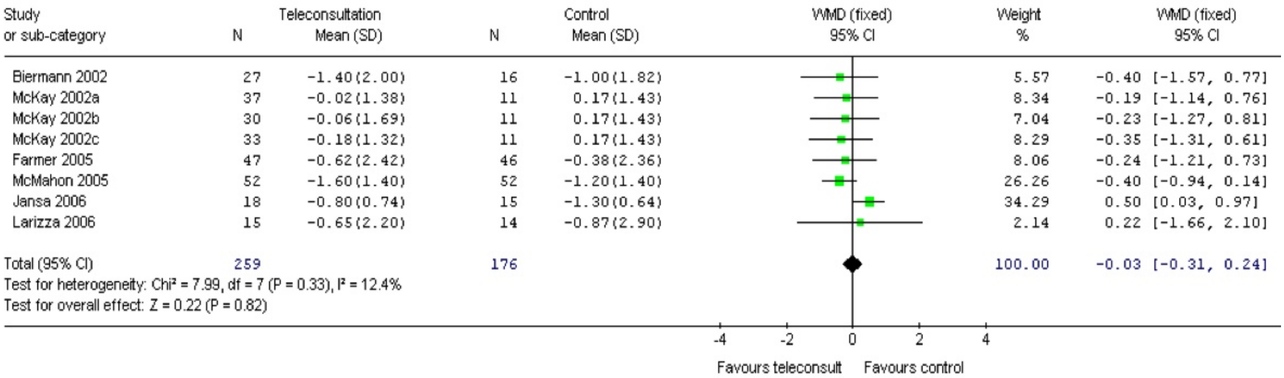
¶Data from location 2 (adults) of the study, see Table 3.

Table 5 presents the mean difference between the baseline and follow-up HbA_{1c} values. These values were either reported in the paper or provided by the authors. None of the interventions were blinded since blinding of participants with respect to study status is almost impossible in clinical trials of behavioral interventions. The method of randomization was not clear in two of the six RCTs; a description of withdrawals and dropouts was given in five studies. The pooled reduction in HbA_{1c} was not statistically significant (weighted mean difference [WMD] 0.03; 95% CI = −0.31 to 0.24). Figure 2 shows the mean difference and WMD of the mean difference between baseline and follow-up HbA_{1c} values. There was no significant statistical heterogeneity among the pooled RCTs (χ^2_7 = 7.99, P = .33). The pooled RCTs included patients with type 1 diabetes [13,15,19,25], type 2 diabetes [31], and unspecified diabetes [27,31]. Glucose monitoring took place via a telephone network

[14,15,19,25,27], the Internet [14,30,31] in primary care [30,31], secondary care [15,19,25], or integrated care [14] settings, or the care setting was not specified [27]. None of the pooled RCTs showed a significant difference in HbA_{1c} between intervention and control groups. The trials varied in duration from 3 to 12 months.

Two RCTs reported a decrease in HbA_{1c} values. In one study [14] (DM type 1, 2, or unspecified), both the intervention and control groups had significantly different variances after 6 months (F test, $P < .05$), confirmed by the results of the randomized subset of patients (t test, $P < .05$) (see Table 3, reported findings under a). The other study [22] analyzed the HbA_{1c} values of children (DM type 1) (see Table 3, reported findings under a). There was no significant difference between the two groups and no significant within-group difference between initiation and completion of the study (6 months). Some observational or quasi-experimental studies showed improved metabolic control with respect to HbA_{1c} [13,16,23,24,33,34], diabetes regulation [33], and glucose, lipid profiles, and blood pressure [31,33]. The improvements were not significant compared to the control group (usual care). The improvements with regard to metabolic control were achieved by means of Web-based care management programs providing patients (mostly DM type 1) who have poor metabolic control with automatic data transmission, educational modules, and messaging systems for communication and personal feedback.

Figure 2. Comparison of changes in HbA_{1c} control versus intervention



Quality of life improved in three studies [17,25,30] (see Table 3, reported findings under b). These studies measured different aspects of quality of life. In one study [17], a mean improvement was realized in the mental and physical status of patients after 6 months of intervention. In the second study [25], an improvement was observed in quality of life (DQOL) and in knowledge (DQK2) in the intervention and control group (usual care). In the third study [30], a slight improvement was reported in psychological well-being, especially in the personal self-management and combined condition.

Effects of Teleconsultation at Behavioral Level

Ten studies [13,16,17,18,22,23,27,28,30,32] reported improvements in patient-caregiver interactions (see Table 3, reported findings under c) with respect to a higher frequency of information exchange (about treatment) and increased metabolic data transmission [16,17,23,30]. In study 16, the intervention was compared to usual care, while in study 17 and 23, the effects were demonstrated in the intervention phase of a cross-over design. In study 30, two of the four care conditions (personal self-management and personal self-management combined with peer support) showed a significant improvement in patient-caregiver interaction. A communication network improved the availability and completeness of data among caregivers [16,23]. Intensity of contacts increased [17,23,30] via daily monitoring and automatic feedback when values were alarming [17], via personal feedback to patients' requests for advice [23] or via an Internet-based program for self-management and social support [30].

Improved self-care was observed in 10 studies [17,18,20,23,25,26,28,31,32,33] (see Table 3, reported findings under d). Patients checked their blood glucose more often [18,31], experienced a better understanding of their medical condition [17,26], and were better able to manage their disease after using the technology [17,18,20,23,25,28,32,33]. Better self-care was achieved in interventions with personal feedback [17,18,20,23,25,26,28] and/or education [28,31,32]. In one study [31], the improvement was significant compared to usual care. Regular data uploads were more likely to achieve and maintain reductions in patients' HbA_{1c}.

Effects of Teleconsultation at Care Coordination Level

In general, most patients were satisfied with the technology (see Table 3, reported findings under e). The technology (eg, glucose meters, hand-held electronic diary) was acceptable for patients [13,23,28,29], was reliable and helpful for caregivers [13,28,33], and appeared easy to use [15,17,21,27,34]. Technical problems and unfulfilled expectations frustrated patients [32]. The availability of metabolic data and the possibility of consulting a caregiver within minimal time and without traveling enhanced patients' feeling of security [15].

Adoption of the technology was demonstrated by a significant increased proportion of transmitted blood glucose data in the intervention group [19]. In most cases, patients were trained to master the equipment [15,17,18,19,20,22,23,25,26,28,30]. Two studies [18,23] reported on the implications of implementing technology in diabetes care. Web-based management of diabetes care [18] changed tasks and duties of the diabetes team as the system required extra competency of nurses in insulin dose adjustments. Electronic communication and frequent blood glucose transmission led to more changes in therapy compared to usual care [23].

Five studies [15,17,21,24,25] reported cost reductions (see Table 3, reported findings under f). Cost reductions concerned saving of consultation time compared to usual care [15,25]. However, teleconsultation significantly increased physician's time since patients tended to call more often [15] and more time was needed to handle technical problems [25]. Costs for technical equipment, telephone, and data transfer were compensated by the cost savings [15]. Costs were calculated as savings per year per patient, reduction of overall utilization and charges after one year, and treatment time required of caregivers. Costs were measured by means of interviews, nonstandardized questionnaires, and by retrieving data from visit logs. A cost analysis was carried out in one study [15] with an estimation of total costs of teleconsultation in an optimized scenario, including a comparison to usual care.

Enhanced transparency was realized in three studies [24,28,33] (see Table 3, reported findings under g). Clinical guidelines for altering diabetes care (a treatment algorithm for metabolic control) resulted in a reduction in HbA_{1c} in patients with poorly controlled diabetes; however, the difference in reduction between intervention and control groups (usual care, actively managed comparator group) was not significant [24]. Protocol-driven data transfer between caregiver and laboratory provided more complete patient records and a significant decrease in metabolic values (HbA_{1c}, lipid profiles, and blood pressure) [33]. Online education of school personal enhanced compliance with school health plans [28].

Studies on the Effects of Videoconferencing and Combined Interventions

Settings and Interventions

Interventions took place in secondary care settings [36,37,40,42,43,45,46] and in primary care [35,38,39,41,44,47,48,49,50,51]. Combined interventions [48-51] were all used in primary care settings, often in underserved or remote areas, to allow videoconferencing to supplement teleconsultation by enabling direct interaction between patient and caregiver(s) [49,50]. Videoconferencing involved real-time contact between the patient at home [37,38,39,40,44,45] or in a local clinic or center [35,36,41,42,43,46,47] and a caregiver in the hospital or diabetes center via video equipment. In 11 cases, patients had contact with one caregiver, while in six cases a team of various caregivers interacted with patients. In studies aimed at patient education [36,41,43,47], consultation took place between patient groups and caregiver(s). Videoconferencing was used for ulcer treatment [35,37,46], for patients discharged from hospital but still needing care [38], for injections and blood sugar control [43],and for general diabetes management [40,42,45]. Feedback was provided mostly during the video sessions or in combined interventions by telephone [49,50] or email [51].

Inclusion criteria for the videoconferencing and combined interventions (see Table 4) included being diagnosed with DM type 2 [35,36,44,47], age [36,39,41,44,47,48,49,50], being treated longer than 1 year [35], being (frequently) referred to a diabetes specialist [47], having a complex medical condition [39,48,49,50], poor metabolic control [39], being at high risk of expensive service visits [48,49,50], being a pediatric patient [42,43], having limited mobility [36], having a caregiver taking part in the intervention [38,39,40,41,45], not having had diabetes education for at least 1 year [41], and having phone access [50]. Three studies did not mention inclusion criteria [37,46,51].

Videoconferencing was chosen because it permitted experts from the hospital to be present in the patient's home while maintaining the continuity and quality of treatment to support disabled or underserved patients [39-41,43,46,49,50]. Combining the two modalities was motivated by the fact that videoconferencing supplements teleconsultation by enabling direct interaction. It was expected that through videoconferencing it would be possible to explain the effects of teleconsultation more accurately [48]. Videoconferencing (and combined) interventions were mainly aimed at cost reduction (n = 14), clinical improvement (n = 11), usability of technology (n = 8), self-care (n = 8), and quality of life (n = 7).

Effects of Videoconferencing and Combined Interventions at Clinical Level

Improved metabolic control was observed in six studies [35,36,39,41,44,49] (see Table 4, reported findings under a).

HbA_{1c} decreased [35,36,39,41,44,49], systolic and diastolic blood pressure decreased [35], total calorie intake decreased, body mass index and glycemic control improved [36], and low density lipoprotein cholesterol decreased [41]. Due to the fact that data regarding standard deviations could not be retrieved, a meta-analysis could not be conducted on the RCTs reporting HbA_{1c} levels.

HbA_{1c} decreased via therapeutic counseling by videoconferencing [35] and by means of daily monitoring of food intake and blood sugar levels via videophone, email, or phone [39].

A comparable reduction in HbA_{1c} was found as a result of educational sessions by videoconferencing with patients in remote areas compared to in-person education (no statistically significant difference between intervention and control groups) [41] and also by monitoring metabolic values and dietary behavior from patient's home with videophone and email (no statistically significant difference between intervention and control groups) [44]. In another study, a hand-held in-home messaging device (Health Buddy), a two-way audio-video link, and a videophone were used to compare weekly monitoring (with a care coordinator) to daily monitoring (with the home message system). HbA_{1c} decreased in both groups (no statistically significant difference between groups) [49].

Most interventions were directed at patients with DM type 2, with poor metabolic control, or with complex medication conditions and a high risk of expensive service visits.

Improvement in quality of life was reported in three studies [36,41,48] (see Table 4, reported findings under b). Two studies [36,41] concerned educational interventions. In one, videoconferencing (video and digital camera) took place in a community center with patients who had limited mobility and skin and foot care (wounds) problems [36]. In the other study, patients at a remote site were connected by videoconferencing, digital camera, and personal computer to a diabetes center [41]. One intervention [48] consisted of a home message system that allowed monitoring and communication by videophone. Quality of life improvements were reported for physical functioning [36,48], general health [36], emotional well-being [36], stress reduction [41], and social functioning [36,48]. Only in one study a control group was used, but no significant difference was observed between the intervention (tele-education) and control groups (education in person) [41].

Effects of Videoconferencing and Combined Interventions at Behavioral Level

Patient-caregiver interaction improved in three observational studies [36,45,47] (see Table 4, reported findings under c). Patients developed a wider social network, creating bonds with both other patients and with caregivers. An interactive ongoing collaboration between patient and caregiver was found to be important for the effectiveness of self-management therapy [45]. Videoconferencing enabled communication between caregivers, to provide education in small groups [47].

Self-care improved in four studies [36,39,41,47] (see Table 4, reported findings under d). Self-care improved by management of blood sugar transfer [39] and increased knowledge allowing patients to cope with diabetes in a better way, thus improving self-care [36]. Patients developed a more positive view of their diabetes [41]. Education via videoconferencing appeared highly acceptable for patients [47]. The improvements in self-care [36,41,47] took place in care settings that were particularly directed at (group) education.

Effects of Videoconferencing and Combined Interventions at Care Coordination Level

Equipment for videoconferencing consisted of a personal computer with video card [35,38,41], equipment with a television [36,42,43,46,47], or a videophone [37,39,44]. A document camera or visualizer was used to show patient records, x-ray images [36,41,43,46], blood sugar values, and pictures of foot ulcers, skin conditions, and wounds. A hand-held camera was used for showing body sites (eg, ulcers) [36,38,42,46,50]. The combined interventions used hand-held in-home messaging devices (Health Buddy) and a videophone for monitoring glucose [48-50].

Videoconferencing equipment [35-37,39-42, 46,47,48,51] appeared convenient and easy to use; caregivers found the photographic images reliable and valid [46] (see Table 4, reported findings under e). seven studies, patients and caregivers were trained to use the equipment [37,38,42,47,49,50,51].

Satisfaction with videoconferencing depended on education and training [51], assistance while using the equipment, and age; the older the patient, the higher the level of satisfaction with videoconferencing [47].

Cost reduction was reported in 11 studies [35,37,38,42,43,45,46,47,48,49,50] (see Table 4, reported findings under f). Cost savings concerned reduced health care utilization [35,38,42,48,49,50], lower treatment costs [38,42], more need-based primary care clinic visits (permitting just-in-time preventive care instead of just-in-case care) [48,49,50], and reduced travel costs for patients [37,46,48] and caregivers [43].

Reduction in health care utilization costs was achieved with respect to hospital admissions [35,49] emergency department visits [42,48,50], hospitalizations [38,42,48], number of bed days of care [48,49], and discharges to home care [38]. Lower treatment costs refer to the potential of videoconferencing to provide the same number of patient encounters at lower cost, decrease patient referrals [38], and replace conventional visits by videoconferencing [42]. Videoconferencing also reduced unscheduled primary care visits [48,49,50]. Studies also associated lower costs with more reliable and valid metabolic control [49,50].

The reductions in costs were found in observational studies without a control group [35,37,42,43,45,47,48]. Costs were calculated during the intervention period and were compared to the costs before the intervention took place (see Table 4, reported findings under f). In three studies [38,49,50], cost reductions were compared to a control group. In one study [38], an economic analysis was carried out on direct and indirect costs occurring at the home health agency level, including labor costs for both the intervention and control groups (skilled nursing home visits only) and costs associated with the implementation of the videoconferencing system. There were no significant differences between intervention and control groups in staff costs (time spent by training, video visits). Total costs per patient per episode were lower for the videoconferencing group, including hospitalization, than for the control group. In two combined interventions [49,50], lower costs were related to more reliable and valid metabolic control. One of these combined studies [49] showed effects of differences in home care monitoring intensities (weekly or daily monitoring) on service costs and clinical outcomes; daily monitoring (transmission via home telehealth technology) significantly reduced the unscheduled primary care clinic visits, the hospital admission rate, and the days of hospitalization. Patients in the daily monitoring group performed better than the weekly (instant camera) monitoring group because of more reliable and valid metabolic control. Although the service cost was reduced, no difference could be found in the clinical outcomes between groups. In the second of these combined studies [50], there were reported differences in health care service use between videoconferencing and conventional care with reference to outpatient services; a difference between intervention and control groups was observed in need-based primary care visits, which increased in the intervention group and decreased in the control group. The likelihood of one or more emergency department visits decreased both in intervention group and control groups, but the intervention group had a lower relative likelihood of having one or more hospitalizations than the control group. Patients who had higher HbA_{1c} levels spent a greater number of days in hospital.

Although videoconferencing saved money, the development and implementation costs (including training of staff) of a new technology are often high, and all kinds of technical problems (and costs) should be taken into consideration. In two studies [38,42], cost savings were compensated by staff training and system costs (including costs of technical deficits). Even when system costs were included, videoconferencing saved money [42] or was estimated to save money on the basis of cost analysis [38].

Enhanced transparency in treatment programs was reported in two studies [37,45] (see Table 4, reported findings under g). Shared documentation via an online ulcer record system enhanced coordination in the treatment of diabetic foot ulcers [37]. A long-term quality improvement program (including national diabetes standards) with an interactive feedback system between patient and caregiver resulted in structured use of staff time [45]. Better access to specialized health care in underserved areas was reported in three studies [42,45,46] and in patients with complex medical conditions in one study [50] (see Table 4, reported findings under e).

Reported Shortcomings of the Studies

Several publications reported shortcomings concerning disappointing or unexpected study results and problems with implementing the intervention. The most frequently mentioned shortcomings were the lack of a significant difference between the intervention and control groups [14,15,19,24-27,30,33,35,36,41,46], the inability to measure long-term effects of the intervention [14,17,19,30,44], and the fact that interventions sometimes inherently led to improved results because of a selection bias. Some patient groups benefited more from the intervention than others (eg, patients with poor metabolic control [33], high use of health care [50], motivated patients [22], or inexperienced patients [15,33,48]).

Some publications reported problems with ICT-based care, generally caused by the absence of adequate infrastructure [14,16,27,29,47,50,51] or the logistical difficulties involved in organizing online consultations, with all parties having to agree on a suitable time [50]. Patient-caregiver interaction suffered from the lack of a protocol that could guarantee high-quality communication, leading to information overload [16,17,18,29,33,51]. In some cases, patients considered the technology too complex to master [21,23,30,47,50,51], too time consuming [15,23,30,33], or too costly [21], and some patients were reluctant to cooperate, resulting in unreliable clinical data transmissions [15,18,26,35,47,51]. ICT-based care was thought to reduce the trust and confidential relationship between patients and caregivers [15,18,32,51].

Discussion

As far as we know, our review is the first to evaluate the benefits of teleconsultation and videoconferencing for diabetes care, in particular with respect to clinical, behavioral, and care coordination aspects. Earlier reviews have focused on usability and costs of technology or considered mainly clinical (glucose and diet) outcomes [2,4,5]. A systematic search and selection process produced only 39 studies. This may appear low, but it is comparable with previous reviews on ICT-based care [3,4,52].

We can conclude that in the period under review (1994-2006), 39 studies had a scope broader than clinical outcomes and involved interventions allowing patient-caregiver interaction. Most of the reported findings concerned satisfaction with technology (26/39 studies), improved metabolic control (21/39), and cost reductions (16/39). Improvements in quality of life (6/39), transparency (5/39), and better access to care (4/39) were hardly observed. In 19 of 39 studies the control group was more or less comparable with the intervention group (see Table 3 and Table 4). It appeared that ICT-based care improved diabetes care compared to usual care; however, the improvements were mostly not statistically significant. In a sense it could be argued that technology did not compromise the care delivery process.

Only a minority of the studies (12/39) considered care settings involving teamwork of various caregivers (eg, nurses, case manager, psychologist, physician, general practitioner), which should be expected in integrated chronic care settings [1,53]. Training was given when implementing the technology, but this was restricted to handling equipment and did not address the technology to solve health care problems, which is a prerequisite for eHealth literacy [54].

The contribution of teleconsultation and videoconferencing to patients' quality of life and ability to control their disease was not substantial (clinical and statistical), because of a limited intervention period and various shortcomings in research design and in implementing ICT-based care. Although previous reviews have indicated that the impact of technology on behavioral change (interaction and self-care) and on care coordination (cost savings) needs to be clarified to support decisions about the use of technology to supplement care [3,5,52], only limited progress was observed. A possible reason that ICT-based care has not shown a high impact on diabetes care could be the absence of a long-term view on the potential of technology to reduce fragmentation and to improve diabetes care at acceptable costs. In most studies, patients' perspectives with respect to emotional and social well-being (quality of life) and ability to cope with diabetes are underexposed, just as the feasibility, appropriateness, and meaningfulness of the interventions for care practice are [55]. Moreover, the choice of a specific technology was mostly based on convenience arguments (access to a computer for instance, living in an underserved area) and not related to preferences and specific needs of patients or caregivers to manage diabetes. For example, a study on the attitude toward videoconferencing [40] showed that patients prefer video visits while nurses wanted to deliver hands-on care in patients' homes. Therefore, it is not certain that the most appropriate technology was used in the most effective way [9], and, consequently, it might be rather premature to say that teleconsultation or videoconferencing as such is the best option to deliver cost-effective and worthwhile services.

Although these shortcomings can be seen as an inevitable part of innovating chronic care, one must consider the benefits of specific technologies to diabetes care to make progress. Based on our review, the benefits of teleconsultation concern the three levels of care. At the clinical level, this implies improvement of metabolic control. Improvements at the behavioral and care coordination level refer to reliable transmission of clinical data (eg, HbA_{1c}), intensified patient-caregiver interaction, and enhanced self-care as a result of an improved understanding of the medical condition and higher quality of feedback (quicker response from caregivers and education about self-management).

Teleconsultation interventions [16,17,19,24,25,31] with improvements in clinical, behavioral, and care coordination outcomes can be characterized as Web-based care management programs providing automatic transmission of clinical values, educational modules, and a messaging system for communication and personal feedback (warning messages and instruction). Conditions for implementing the technology were reported in some of these studies, such as using computer-based patient records for electronic data interchange between caregivers; guidelines for writing medical records; a close cooperation between patient, general practitioners, and specialists [16]; access to a care manager to manage diabetes care with technology; and patients who favor ICT-based care [31]. The technology was found not advanced enough to be sufficiently practical and cost-effective [25], and more intensive techniques (like computerized decision support systems) are needed to help patients change their health behavior [19].

Most of the studies reported none or limited information about preference for and persistence of technology for specific patient groups. The observed improvements were based on interventions directed at patients who were able to use the equipment (eg, having experience with cell phones and SMS) [14,17,18,20,21,26], who were well motivated to take part in the intervention [13,14,15,31,33,34], who already had a caregiver taking part in the intervention [17,24], who were economically disadvantaged [17,28], or who had type 1 diabetes that required strict monitoring of blood glucose levels [22,23,25,28]. This might confound the practicability of the results [55,56].

The benefits of videoconferencing can be particularly demonstrated at the usability level (convenient and easy to use) and care coordination level. Videoconferencing appeared to maintain quality of care while producing cost savings in patient at-home care settings. Real-time communication appeared particularly successful in group education, allowing patients to take more proactive roles in managing their diabetes, helping them to feel happier and to develop wider social networks. Monitoring combined with videoconferencing enabled "just-in-time preventive care" instead of more expensive "just-in-case care" and significantly reduced unscheduled clinic visits, hospital admissions, and days spent in hospital. Cost savings should be offset by increased staff costs and the costs of the development and implementation. For instance, increased patient-caregiver interactions or increased need-based primary care may imply an increase in workload. In two [38,42] of the 11 studies on cost savings, the cost reductions were compared to increased system costs.

The results were based on interventions directed at patients in underserved or remote areas, with complex medical conditions (elderly, immobile, or with poor metabolic control), or meeting some practical conditions, such as having access to a physician in the intervention setting, which should be taken into account when implementing videoconferencing in practice, for reasons of selection bias [55,56].

Successful interventions [38,41,48,49] with improvements in clinical, behavioral, or care coordination levels included programs aimed at teaching patients to cope with and control their diabetes, mostly settings in which patients at home consulted with their caregivers at hospitals or diabetes centers via video. Reported conditions for implementing these interventions were training of patients and staff throughout the implementation to learn to deal with the equipment [38], alternative markets to reduce investment costs, like purchasing "used" equipment at reduced costs [38], and a health care system that has an ongoing and well supported clinical infrastructure to support professionals competent to deal with ICT-based care [48].

The observed benefits are consistent with prior reviews regarding cost savings, efficacy of applications, and improved communication between primary and secondary health care providers [4,5,9,52,57]. The scope of the reviews differs from our study, which is particularly aimed at diabetes care.

Some Limitations of Our Study

Due to the diversity and variance in study designs, inclusion criteria, and a lack of required data, a meta-analysis could not be conducted on the RCTs reporting HbA_{1c} levels (videoconferencing) and other outcomes (quality of life, behavior, and care coordination). In particular, studies on quality of life, behavior, and care coordination used different outcome measures or calculated the same outcome (eg, well-being) in different ways. Lack of required data hampered a statistical combination and therefore may have biased the review's results. To avoid spurious preciseness, we did not combine observational studies for a meta-analysis.

To evaluate the contribution of technology to diabetes care, we developed a checklist based on principles for chronic care [1,53,58] because existing evaluation systems are directed at usability and acceptability of equipment rather than care service delivery [9]. Future research should validate this checklist. We reported the outcomes of the interventions per level of care, although they are interdependent in a chronic care setting; the usability of the equipment influences the reliability of monitoring and patient-caregiver interaction, which can influence behavior and care coordination [1].

We chose to review various systems of teleconsultation and videoconferencing to shed light on different functions of the systems (monitoring, information exchange, communication) to support diabetes care. This might increase the heterogeneity in our study results.

Future Research

When patient self-care and care coordination are the focus of the intervention, we need to evaluate the process of implementation more thoroughly (eg, which patients persist and which drop out) and the quality of communication. We observed that patients need more help with self-care than they received in the intervention settings, and online training and personal assistance might be necessary in cases of ICT-based care. A supportive health policy environment (and appropriate financing) is necessary to guarantee continuity after a pilot period. Successful diabetes management systems should integrate several functions to provide collaborative care and to meet the needs of patients and caregivers. Moreover, the shift from hospital to community centers or home care requires technology that integrates lifestyle and education functions for simultaneous group education and for encouraging self-care. Future research should be directed at the development of patient-centered technology personalized to specific needs and capacities. More rigorous methods are needed to measure the effects of an intervention on quality of life, well-being, and organizational issues such as cost effectiveness to make decisions on implementation and to encourage better care coordination. By means of usability tests and log files, patients' needs for care and technology support can be measured, and test results can be linked to education and behavior changes [59]. By means of critical incidents techniques [60], the conditions that permit technology to be implemented successfully can be assessed. More transparency is needed in reporting economic evaluations. The costs included in the studies varied so that comparison of the reported savings is hardly possible, which is also demonstrated in a former review [57]. Cost effects should be studied with a clear perspective that reflects the purpose of the evaluation and the viewpoint of analysis (eg, cost-benefit, cost-effectiveness analysis).

We conclude that further assessment studies are needed to evaluate the contribution of ICT-based care to diabetes management. Future research should examine the potential of technology to enhance self-efficacy with the aim of making life worth living for someone with certain limitations, in cases where the disease is incurable. Technology can easily overstress the negative aspects of disease and illness because of the focus on collecting health data (eg, food intake). In the end, self-efficacy and social support are possibly the main conditions for changing health behavior [61].

Conflicts of Interest

None declared.

Multimedia Appendix

Extended Tables 3 and 5 (containing inclusion criteria and data gathering methods): Overview of videoconferencing and combined interventions [PDF file (Adobe Acrobat), 196 KB - jmir_v9i5e37_app1.pdf]

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Abbreviations

DM: diabetes mellitus
HbA_{1c}: glycosylated hemoglobin
ICT: information and communication technology
RCT: randomized controlled trial

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Original Paper

Mobile Web-Based Monitoring and Coaching: Feasibility in Chronic Migraine

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Abstract

Background: The Internet can facilitate diary monitoring (experience sampling, ecological momentary assessment) and behavioral coaching. Online digital assistance (ODA) is a generic tool for mobile Web-based use, intended as an adjuvant to face-to-face or Internet-based cognitive behavioral treatment. A current ODA application was designed to support home-based training of behavioral attack prevention in chronic migraine, focusing on the identification of attack precursors and the support of preventive health behaviour.

Objective: The aim was to establish feasibility of the ODA approach in terms of technical problems and participant compliance, and ODA acceptability on the basis of ratings of user-friendliness, potential burden, and perceived support of the training for behavioral attack prevention in migraine.

Methods: ODA combines mobile electronic diary monitoring with direct human online coaching of health behavior according to the information from the diary. The diary contains three parts covering the following: (1) migraine headache and medication use, (2) attack precursors, and (3) self-relaxation and other preventive behavior; in addition, menstruation (assessed in the evening diary) and disturbed sleep (assessed in the morning diary) is monitored. The pilot study consisted of two runs conducted with a total of five women with chronic migraine without aura. ODA was tested for 8.5 days (range 4-12 days) per participant. The first test run with three participants tested 4-5 diary prompts per day. The second run with another three participants (including one subject who participated in both runs) tested a reduced prompting scheme (2-3 prompts per day) and minor adaptations to the diary. Online coaching was executed twice daily on workdays.

Results: ODA feasibility was established on the basis of acceptable data loss (1.2% due to the personal digital assistant; 5.6% due to failing Internet transmission) and good participant compliance (86.8% in the second run). Run 1 revealed some annoyance with the number of prompts per day. Overall ODA acceptability was evident by the positive participant responses concerning user-friendliness, absence of burden, and perceived support of migraine attack prevention. The software was adapted to further increase the flexibility of the application.

Conclusions: ODA is feasible and well accepted. Tolerability is a sensitive issue, and the balance between benefit and burden must be considered with care. ODA offers a generic tool to combine mobile coaching with diary monitoring,independently of time and space. ODA effects on improvement of migraine remain to be established.

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KEYWORDS

Personal digital assistant; ecological monitoring; electronics; migraine; health behavior; self-care; patient compliance; patient satisfaction

Introduction

This paper presents a pilot study to test the feasibility and acceptability of a new method for mobile Web-based monitoring and coaching. Online digital assistance (ODA) was developed to monitor health and to coach health behavior in real life, independently of time or space, and as an adjuvant to cognitive behavioral treatment. ODA runs on advanced clinical software [1] and is executed through a personal digital assistant (PDA) or cellular phone with integrated Internet facility.

The monitoring feature of ODA is based on the electronic diary method of experience sampling [2,3] or ecological momentary assessment [4-6], employed in health psychology research [7-9] to reliably measure symptoms [10-12], momentary mood [13], or other fluctuating states in near real-time. PDAs are programmed to produce randomized calls, which prompt participants to answer diary items with the PDA keyboard or soft-touch screen. This generates valid real-time assessments of momentary health status and functioning, which are unbiased by anticipation or retrospection. The coaching feature of ODA is based on the possibility of connecting PDAs or cell phones wirelessly to the Internet, which permits tailoring feedback and behavior directives to users based on their information in the momentary diary. This requires specific software, called ODA 1.0, which was developed by students in the Utrecht University Department of Information and Computing Sciences [1].

ODA development was instigated within a Dutch trial on the effectiveness of a home-delivered behavioral training program conducted in 100 patients with chronic migraine [14,15]. Behavioral training in migraine is challenging [14] because the focus on attack precursors and preventive health behavior is counterintuitive to the attitudes and habits of many migraine patients. ODA monitoring could support the timely detection of attack precursors (the first behavioral training goal). This is essential because migraine precursors are elusive, and patients tend to focus on the agony of the attack and ignore its premonitory stage. ODA coaching could reinforce proactive behavior to prevent attack occurrence (the second behavioral training goal).Behavior to slow down and sooth nervous system activation and brain stem disruption in the hours preceding the breakthrough of an attack is crucial, but it is contrary to the habit of many patients of increasing efforts and pushing toward finishing things in time before the pain strikes. Therefore, our first application of the ODA method pertained to supporting the identification of attack precursors and the execution of preventive health behavior in these patients.

We will present data on the feasibility and acceptability of this ODA application in five migraine patients [16,17]. ODA feasibility was assessed in terms of the technical problems encountered and participant compliance with the application. Technical problems are not expected to arise within the PDAs, which are quite robust. The ODA software and data transmission through the Internet could, however, encounter obstructions and thus induce data loss, which had to be evaluated. With respect to ODA participant compliance, we aimed to establish what proportion of diary prompts would be answered, which is a metric for compliance in experience sampling and ecological momentary assessment research [2-4].ODA acceptability was established on the basis of participant ratings of ODA user-friendliness, potential burden, and perceived support of behavioral attack prevention in migraine.

Methods

Participants

This study was conducted with five women with chronic migraine without aura [18]. The participants had successfully completed behavioral training and thus were well acquainted with its principles and aims. The first test run with three participants tested 4-5 prompts per day. The second run with another three participants (including one subject who participated in both runs) tested a reduced prompting scheme (2-3 prompts per day) and minor adaptations to the diary (Table 1). The Medical Ethics Review Committee of Utrecht University Medical Center approved the study.

Table 1. Characteristics of participants in the pilot study

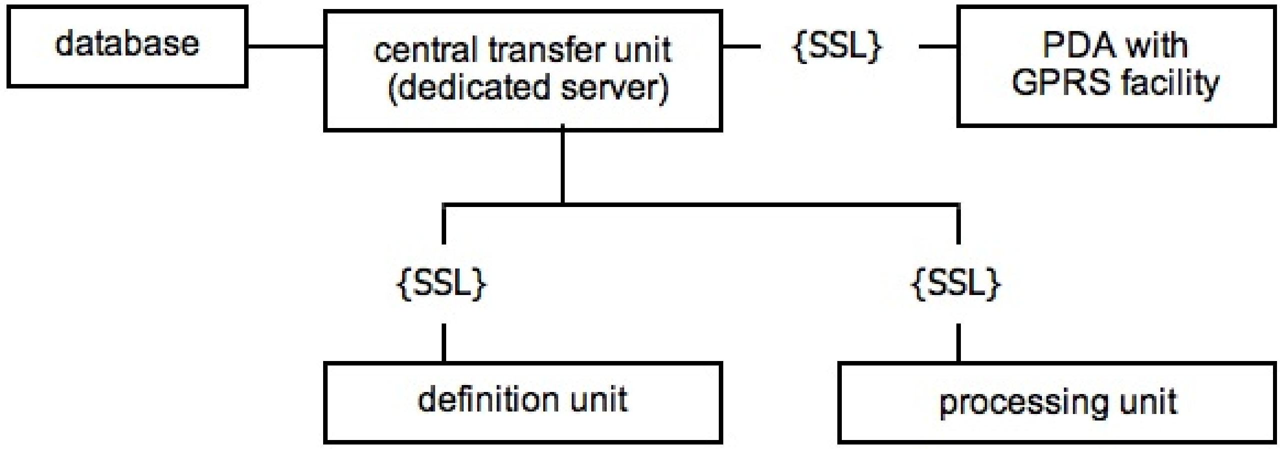
Participant	1	2	3	4	5
Run	1	1	1 and 2	2	2
Age (years)	34	39	43	24	52
Profession	administrative employee	career advisor	industrial designer	psychologist	teacher
Marital status	married	single	single	married	married

ODA Software, Monitoring, and Coaching

ODA Software

A generic toolbox was built to allow adaptations to user characteristics and to the needs of researchers and clinicians. A convenient interface was promoted by keeping user actions to the utmost minimum and by facilitating the provision of online feedback. Privacy protection was assured by a dedicated server and Secure Sockets Layer (SSL), by authorization of users as well as researchers and clinicians through a personal log-in code and password, and by user-chosen nicknames. To avoid data loss, diary answers were separately saved on the server. The ODA software was extensively tested and reached its second milestone version [1]. It runs on Linux, supported by the software components Apache Web Server, Java, PostgresSQL, and Tomcat, and data encrypting is authorized by SSL certification. Figure 1 displays the units of the ODA software.

Figure 1. Design of software application ODA 1.0/1.1



The definition unit serves to establish the design and setup of a given ODA application. This includes the documentation of demographics, diagnostics, and other particulars per user, such as type and dose of medication intake; the allocation of feedback providers (researchers or clinicians) to users; and the definition, handling, and storage of log-in codes, passwords, and user nicknames. Specifics of ODA monitoring are also defined here and include the diary editing, choice of answer categories per item, and the branching of items (meaning that the appearance of questions depends on the type of answer for a preceding question).

The processing unit handles the provision of the feedback for ODA coaching. It identifies the human feedback provider by log-in code and password, supplies Short Message Service (SMS) notification of completed diaries, and provides access to all current and archived user diaries. This unit also draws the attention of the feedback provider to extreme diary answers or patterns of scores by so-called alerts, which appear on a separate screen. The alerts underscore salient aspects of the diary, such as risk conditions or positive functioning, which are weighted against pre-programmed thresholds. Data are stored in ASCII files with a fixed matrix of variable names covering the time-stamped electronic diaries and feedback per user. These ASCII files are transformed through Excel for Windows (Microsoft Corporation, Redmond, WA, USA) into files suitable for data analysis in SPSS 14.0 (SPSS Inc, Chicago, IL, USA).

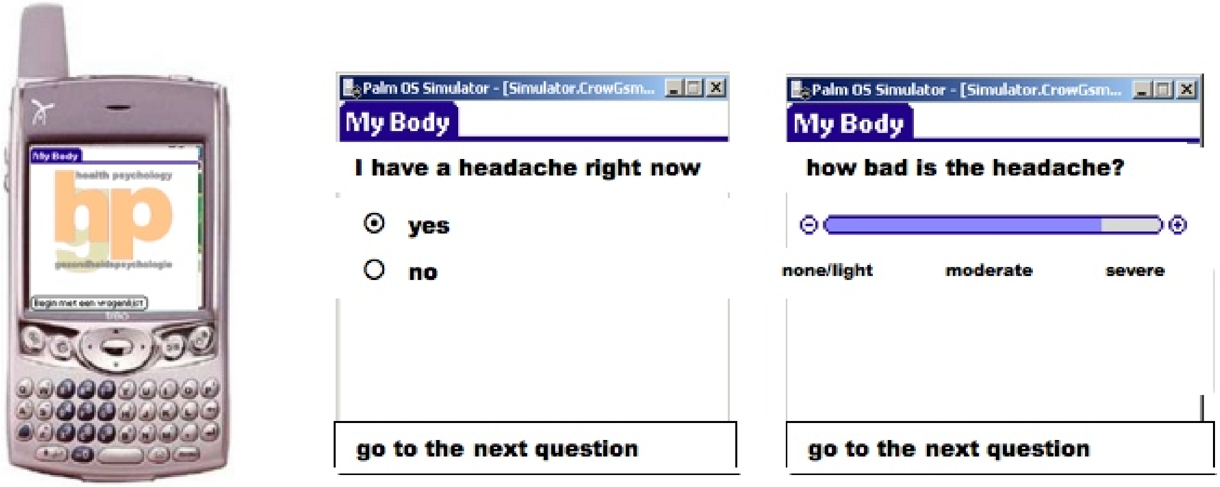
The PDA is pre-programmed with diary timer software developed at our institute and adapted to supplement the ODA software while optimizing the user-friendliness of the application [19]. The diary timer disables irrelevant PDA functions such as video recording and picture taking and locks the use of other PDA software. Primarily, however, it fine-tunes the electronic monitoring by creating and handling the prompting scheme. Pre-programmed definitions of this scheme involve the mean interval between calls, the variation range in random occurrence of the calls around these time points, and the desired interval (in minutes) between the repetitions of prompts per call. The diary timer also provides user options to regulate the volume of the prompting signal or chose a silent visual prompting mode for specific occasions (such as when attending a church service, meeting, or concert). It also provides a researcher option to limit the maximum duration of the silent prompting per day. Each day, the diary timer activates a randomized prompting scheme when the user enters a morning diary upon awakening, and it deactivates the prompting when the user enters an evening diary before going to sleep, which closely adapts the diary prompting to the individual wake-sleep cycle of the users. This function is new in electronic diary monitoring. It offers a strong advantage to user-friendliness, but it also weakens methodological control over the total number of calls per day, which depends on the duration of the user's awake time. The diary timer produces a daily log file of the following: the times the user wakes up and goes to bed, all calls, number of prompts per call, and diary completion times.

Electronic Diary and Monitoring

The ODA electronic diary is constructed according to the principles of experience sampling [3,6,11]: momentary functioning is captured by items that are short, unambiguous, grafted on the actual moment (right now), and that mimic the internal dialogue of the respondent through self-statements in colloquial language. Positively and negatively phrased items are balanced to avoid response tendencies, and answer categories include multiple choice, yes/no, and open answers, as well as visual analogue scales. Figure 2 shows the PDA (PalmOne Treo 600, Palm Inc, Sunnyvale, CA, USA) and examples of diary items as they appear on the PDA screen.

In experience sampling, a morning diary, an evening diary, and a day (beep) diary are employed. The user initiates a morning diary upon awakening to review the previous night and initiates an evening diary at bedtime to review the current day. Diaries during the day are prompted by randomized auditory calls or beeps. The frequency of this beep diary depends on the purpose of a given application. Usually, high-density monitoring with ≥ 10 beep diaries per day is confined to one to several days [20,21], while frequencies of four to six beep diaries per day may extend over weeks [10-12]. Responder compliance was satisfactory in applications of monitoring only [10-12,20], but in ODA several calls per day could be tolerated less well because the responder also receives ODA coaching and thus has additional tasks.

Figure 2. The PDA currently used for ODA and examples of diary items with response options

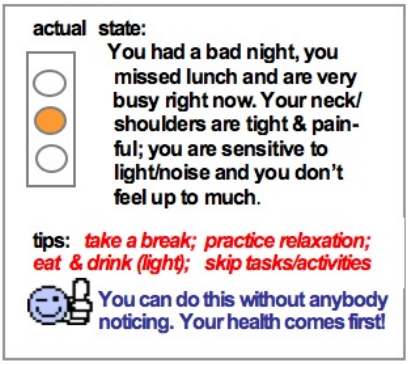


Coaching

The ODA software permits the provision of feedback that is fully automated [22]. The current focus is on the delivery of personal feedback that is closely tailored to the individual, thereby personalizing Web-based interventions to empower behavior change and self-care [23]. Feedback providers have exclusive access to the diary data of allocated participants and take care of all the feedback to those users. They remain anonymous, have no other contact (either direct, mail, or phone), and know the user exclusively by his/her nickname and diary entries.

The feedback consists of three sections (in different colors on one page of the PDA screen) pertaining to the user's actual state, tips for the user, and a pep-up statement. The software provides a second page to be scrolled through by the user, but this is rarely used. Feedback on the user's actual state consists of a summary of salient information from the last diary regarding health risks or well-being accompanied by one of five color codes (green, green and orange; orange; orange and red; red) on a traffic light. Tips are behavioral directives for preventive self-care. Pep-up statements express encouragement, praise, support, or understanding of difficulties. They reinforce the execution of the tips and are underscored by an emoticon. Figure 3 provides an example.

Figure 3. Example of the components of ODA feedback taken from the present ODA application in migraine



ODA coaching is performed on laptop or desktop computers but can also be handled through a PDA. The evident advantage is that the feedback provider is mobile with the PDA, but its small screen hampers full inspection of the material to some extent. The feedback provider has access to each new diary and the ODA archive through log-in and password entrance to the ODA processing unit. Each new diary is accompanied by a record of alerts to gear the composition of the feedback. The current ODA application for migraine contains 17 alerts pertaining to healthy functioning, prevailing migraine headache or attack precursors, and the preventive health behavior employed by the user. Each alert is presented with its pre-programmed threshold and the diary scores involved. When composing the feedback, a written protocol of colors assigned to a 5-stepped hierarchy of health risks [16,17] dictates the choice of the traffic light, the emoticon is chosen from a programmed list of smileys, and the text is written as focused and condensed as possible. After checking the spelling and the match between text and graphics, the feedback is transmitted to the PDA of the user with an SMS notification that it is available.

Procedures

Specifics of ODA Monitoring and Coaching

In run 1, subjects were signalled randomly in 2.5-hour time units, which represents a scheme of four to five calls per day, based on the compliance with comparable prompting in experience sampling studies in migraine [10], chronic pain [11,12,24], and severely fatigued subjects [25]. The prompts extended until 9:30 or 10:00 pm [10-12]or continued until bedtime [25]. Run 1 revealed annoyance with this number of calls per day, however. Annoyance would affect ODA tolerability and provided that the demands of behavioral training [14] limit the readiness of participants to invest extra effort, this would threaten the main study in which we intended to provide ODA while participants were undergoing behavioral training.

Therefore, a scheme of two to three calls per day was tested in run 2. In both runs, the option to put the prompting signal into silent mode was set at a maximum of 2 hours per day, and prompts were repeated three times per call with intervals of 1 minute. A beep diary not filled in after the third prompt was stored as a missed entry, and completely and partially entered diaries were automatically saved. Online coaching was confined to workdays and was provided twice per day by masters students in clinical and health psychology who were trained and supervised by the fourth author. For their convenience, they were allowed to incidentally provide feedback through a PDA.

Briefing and Debriefing

Participants were visited at home for 60-90 minutes of ODA demonstration and instruction and the signing of an informed consent form. They received a PDA with an instruction booklet and a phone number and email address to contact the researchers in case of questions or technical problems. The test run lasted for 8.5 days on average (range 4-12 days). After completion, the PDA was collected from the user's home, ODA was evaluated, and the participant received a small gift.

Instruments

Diary

The current 40-item beep diary contained three parts covering the following: (1) migraine headache and medication use, (2) attack precursors, and (3) self-relaxation and other preventive behavior. Items for part 1 were based on international diagnostic criteria [18] and adapted from items that had been successfully employed in previous studies [10-12]. Part 2 consisted of new items representing three classes of premonitory symptoms (eg, physical, affective-cognitive, behavioral) and triggers (eg, food intake, external strain, climatic conditions) of migraine attacks, derived from a literature review [16,17]. Items for part 3 were drawn from the behavioral training evaluation forms [14,15]. The 18-item evening and 19-item morning diaries included the items from part 1 of the beep diary as well as items for two additional migraine triggers: menstruation in women (assessed in the evening diary) and disturbed sleep (assessed in the morning diary).

Evaluative Questionnaire and Interview

The evaluation of ODA took place during the debriefing meeting at the user's home. Participants filled in an evaluation form consisting of 11 items on user-friendliness, subjective compliance, the impact and potential burden of ODA, and the degree to which ODA supported the goals of behavioral training. The form included an open space for comments. This was complemented with a structured evaluative interview that focused on the peculiarities of handling the PDA, adhering to instructions, and managing eventual problems and on the positive and negative experiences with the system.

Results

Feasibility

Technical Problems in ODA

The loss of data due to technical problems amounted to 6.8% (11/161) potential diary entries. Minor internal problems occurred within the PDAs as expected and were solved by having the user reset the PDA. They accounted for a loss of 1.2% (n = 2) of the diary entries. External causes such as buildings or atmospheric influence incidentally hampered Internet transmission and thus receipt of the diary prompt by the user, which accounted for 5.6% (n = 9) of lost diaries. An initial software problem obstructed the storage of part of the feedback in run 1.

Compliance With ODA Monitoring

Table 2 summarizes the particulars of ODA monitoring and coaching separately for each participant and aggregated per run. In run 1, the mean compliance of 78.6% for the beep diary was just below the ≥ 80% criterion for good compliance, mainly due to participant 2 who missed almost half of the diary calls. The mean compliance in both runs was 80.1% for the beep diary, but in run 2, compliance with the beep diary was good (86.8%), as was the compliance in both runs with the morning and evening diaries.

Table 2. Objective compliance with ODA monitoring

	Participant						Total Run 1		Participant						Total Run 2	
	1		2		3				3		4		5			
	No.	Mean or %	No.	Mean or %	No.	Mean or %	No.	Mean	No.	Mean or %	No.	Mean or %	No.	Mean or %	No.	Mean
ODA monitoring																
Number of days	10		4		6		20	6.7	8		11		12		31	10.3
Number of diary calls*	41	4/day	16	4/day	30	5/day	87	4.3/day	21	2.6/day	25	2.3/day	28	2.3/day	74	2.4/day
Problems connecting to Internet	2		1		0		3		0		1		5		6	
Missed diary calls†	5	12.8%	7	46.7%	6	20%	18	21.4%	2	10%	5	16.7%	2	13%	9	13.2%
Completed beep diaries†	34	87.2%	8	53.3%	24	80%	66	78.6%	19	90%	19	83.3%	21	87%	59	86.8%
Completed morning diaries	8	80%	4	100%	6	100%	18	90%	7	88%	11	100%	7	58.3%	25	80.6%
Completed evening diaries	9	90%	4	100%	6	100%	19	95%	7	88%	9	81.8%	9	75%	25	80.6%
ODA coaching																
Number of workdays	6		4		4		14	4.7	6		7		8		21	7
Number of times feedback was given‡	9	1.5/day	3	0.8/day	7	1.8/day	19	1.4/day	12	2/day	14	2/day	16	2/day	42	2/day

*The number of calls per day depended on the setup (4-5 calls in run 1; 2-3 calls in run 2). The variation in calls received by the user depended on the time between wakeup and going to sleep, which differed between participants and between days per participant.

†Calls obstructed by Internet transmission problems were subtracted from the total number of calls in computing the percentages.

‡The days with feedback differed from the days of monitoring because feedback was not provided on the weekends, while monitoring continued. In run 1, an initial problem in data storage that was permanently solved accounted for smaller numbers than the feedback that had actually been provided.

Acceptability

The findings from the 11-item ODA evaluation form are summarized in Table 3. Two of the three participants in run 1 objected to the number of diary calls per day. This was not the case in run 2, when the number of calls had been reduced. Since this was the only difference in the two runs, the remaining scores were averaged for the total group (last two columns of Table 3).

User-friendliness was rated positively regarding the handling of the PDA, readability of the screen, ease of answering diary questions, and clarity of the instructions. Perceived compliance with responding to the first prompt per call ranged from 50% to 75%. (Note that the computed compliance presented in Table 2 represents the response to all prompts per call.) The impact of ODA on daily living was consistently perceived as relatively low, as was the experienced burden (notwithstanding the dissatisfaction with the number of calls in run 1). According to the participants, ODA supported the key targets of behavioral training to a considerable extent, and 80% were ready to participate again.

Table 3. Perceived user-friendliness, compliance, impact, and behavioral training support of ODA

	Run 1 * (N = 3)		Run 2 * (N = 3)		Run 1 and 2 (N = 6)	
	Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**
User-friendliness of the PDA †						
Did you have trouble handling the PDA?	1.7	1-3	1.0	1	1.4	1-3
Did you have difficulties reading the words on the PDA screen?	1.7	1-3	1.0	1	1.4	1-3
Could you conveniently answer the diary on the PDA?	3.7	3-4	4.0	4	3.9	3-4
Were the instructions clear to you?	3.3	2-4	4.0	4	3.7	2-4
Immediate compliance with online monitoring ‡						
How often did you fill in the diary directly after the first prompt?	2.7	2-3	2.0	1-4	2.3	1-4
Impact of ODA †						
Did you experience your participation as a burden?	2.3	2-3	2.0	2	2.2	2-3
Did the study influence your daily life?	2	1-3	2.3	2-3	2.2	1-3
Was the number of calls per day annoying?	3.3	2-4	1.3	1-2		
Would you agree to participate again in a comparable study?	4	4	3.0	2-4	3.5	2-4
ODA support of behavioral training key targets †						
Did the diary help detect early symptoms and migraine triggers?	2.7	2-3	3.3	3-4	3	2-4
Did the feedback help you to take actions to prevent an attack?	3	3	2.7	2-3	2.9	2-3

*Run 1: 4-5 calls/day; run 2: 2-3 calls/day.

†1 = no/not; 2 = somewhat; 3 = considerably; 4 = very much.

‡1 = in less than 50% of the beep diaries; 2 = in approximately 50%; 3 = in approximately 75%; 4 = in almost all beep diaries.

The participants' comments and responses in the evaluative interview underscored that ODA was confronting in the sense that it induced awareness of the user's denial of premonitory symptoms and then counteracted this neglect. ODA was also said to have induced timely and more frequent self-relaxation, pacing down, and careful attention to actual personal needs. ODA coaching was experienced as an essential incentive that made the difference in actually taking measures against overexertion. Interestingly, the existence of an external voice or person was regarded as decisive in this matter. ODA was not automatically or directly accepted—it required time for the users to become acquainted with and get used to. When this was accomplished, the PDA providing ODA was experienced as a supportive little helper or companion, conveying that one is not left alone and that migraine self-management is a shared problem. Consequently, some of the participants asserted to have missed the feedback on the weekends, and one participant dreaded handing in the PDA.

Discussion

This study showed that ODA successfully produced electronic diaries of momentary state and functioning (provided online by users) as well as direct coaching of health behavior (provided online to users by trained research assistants). Data loss due to internal causes was negligible (1.2%) and was acceptable when due to external causes (5.6%). Compliance with ODA monitoring was > 80% (86.8% in run 2), user-friendliness was confirmed, and the perceived burden was low. ODA did not disturb normal life to any considerable degree and was well accepted and appreciated by the participants.

We underscore that ODA was developed not to refine experience sampling methodology, per se, but to provide a mobile tool for online monitoring and coaching as an adjuvant to face-to-face or Internet-based cognitive behavioral treatment. Below we discuss issues in ODA development, technical problems, and potential data loss and issues of ODA tolerability.

ODA development was not an easy venture. Part of the difficulty arose from the fact that the sales information of PDA-producing companies insufficiently covered areas of internal functioning, which were specifically relevant to applications such as ODA. As far as we can see, this holds for all PDAs on the market and applies also to cell phones. The PDA Internet facility, in particular, had flaws obstructing the development of ODA. Problems popped up unexpectedly irrespective of the degree of software testing, and in our experience, these could be solved exclusively through Internet communication with other users of the hardware at issue. These problems were handled before the execution of the present pilot study. Within this study, the performance of ODA encountered few PDA-intrinsic problems after the devices were handed out to the users (1.2%).

An important source of data loss to be considered was Internet transmission problems due to external conditions such as buildings or atmospheric influence. These external causes induced a data loss of 5.6% in the present study, which was considered acceptable. The flaw was not due to ODA software or hardware or to problems of users. There were other external sources of potential data loss as well. We encountered an impending disturbance in the receipt of the feedback due to irregularities induced by the SMS provider, and the server was blocked for several hours because of unannounced maintenance work. Fortunately, both events did not induce actual data loss. These underscore, however, that services provided by external agencies for SMS delivery or server hosting demand watchful attention.

Tolerability and acceptability of ODA protect against data loss due to non-adherence. Tolerability is a particularly sensitive issue when ODA is used to support cognitive behavioral treatment because burdening or annoying participants could hamper instead of promote progress of the intervention. Migraine sufferers had accepted six prompts for more than 2 months of electronic diary keeping [10], and subjects with chronic pain [11,12] or fatigue [25] had tolerated four to five prompts per day for 2 to 4 weeks. Two of the three participants objected to this number of prompts in run 1 of the present pilot study. This finding may be coincidental, given the small number of subjects. We took it seriously, however, because ODA can be demanding, and careful attention should be devoted to prevent the accumulation of burden.

We present four potential threats to ODA tolerability. First, users may be bored if diary items are not presented flexibly through branching logics. We took this risk in part 2 of the present diary where bulky sets of items were required to cover potential premonitory symptoms of the migraine attack. All of these potential symptoms had to be explored in each diary because, thus far, they were poorly understood in the empirical literature. Second, in the present ODA application, diary answers were saved separately to the database to guard against data loss. As a consequence, respondents had to wait briefly after each answer, and the average diary completion time was 8 minutes instead of 5 minutes in previous studies. The present findings show that data loss was limited in ODA. We therefore recommend against separate answer transmission through the Internet because the advantage of speed and fluency of the diary completion seems to outweigh the gain of preventing extra data loss. Third, in ODA, diary monitoring is not the only task. The feedback from online coaching also requires attention, and the feedback was, at times, experienced by the user as confronting and thus might have been energy consuming. This implies that ODA coaching could be burdening in its own right. Fourth, it deserves considering that PDAs might have been accepted particularly well in early experience sampling studies because at that time they were a novelty gadget [10]. At present, however, interruptions from mobile devices are burdening [26] and meet zero tolerance in many circumstances. Therefore, this might also threaten the tolerance of ODA and electronic monitoring in general.

These issues underscore that the combination of online monitoring and coaching involves participants more strongly than monitoring alone did in previous studies and that ODA requires a careful account of the balance between benefit and burden. All the factors mentioned here could affect ODA tolerance, which could, in turn, be reinforced by the demands of being under treatment. In order to optimize ODA tolerance, we took measures to increase ODA flexibility based on the present findings. The ODA software was accustomed to saving diaries on the server upon completion, which produces a 40% reduction in the completion time of equivalents of the current diary, and the diary timer software was adopted to restrict calls to certain times of day or to exclude prompting in the evening when desired while keeping the adaptation to the individual wake-sleep cycle of the users. New steps in technology development concern full implementation of ODA in cell phones and extension of the ODA software to create individualized graphical representations of selected diary scores, which provides users with fully automated feedback on the course of their health status over time. Currently, we are linking ODA to Web portals and other eHealth applications. One possibility concerns connection to a German system for computer-aided therapy [27] that shares the same software basis.

We conclude that we succeeded in developing a new tool for mobile Web-based monitoring and coaching. ODA feasibility and acceptability are attainable, and ODA can be used conveniently to assess momentary functioning and to deliver direct feedback and behavioral directives while reaching people independently of time and space. ODA fulfilled its specific promise to the current application in migraine: reinforcing risk detection and behavioral attack prevention, the central goals of behavioral training in migraine. We underscore that the present findings can not be generalized to other populations that might be less motivated or show higher attrition rates. Large-scale use of ODA is not warranted as yet since ODA effectiveness remains to be established. This is at issue in a current study of the ODA application in migraine.

ODA could easily be extended to other areas using shorter diaries and the inclusion of fully automated feedback. A potentially promising field is that of health maintenance and optimal functioning in corporate organizations. The present paper may encourage efforts in other fields, particularly areas in which lifestyle change prevails and mobile contact is practical. ODA intended as a supplement to Internet-based cognitive behavioral intervention may also have potential in its own right as a tool in research or clinical practice to support prevention and health self-management.

Last, we point out that participant comments in the current ODA feasibility study hint at intriguing new issues in eHealth. The PDA was experienced as a personal companion and helper with a voice. This experience was crucial in instigating action, actual goal-directed behavior, and preventive self-care. Could it be that mobile digital devices come closer to the individual and have greater potential to actually change health behavior than current media-transmitted health education and prevention programs? This is a challenging question that, in our view, deserves serious research attention.

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Conflicts of Interest

None declared.

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Original Paper

Feasibility of a Mobile Phone–Based Data Service for Functional Insulin Treatment of Type 1 Diabetes Mellitus Patients

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Abstract

Background: Patients with type 1 diabetes mellitus (DM1) have to be active participants in their treatment because they are inevitably responsible for their own day-to-day-care. Availability of mobile Internet access is advancing rapidly and mobile phones are now widely available at low cost. Thus, mobile phones have the potential to assist in daily diabetes management and to enable a telemedical interaction between patients and health care professionals.

Objective: The aim of the study was to evaluate the feasibility and user acceptance of a mobile phone–based data service to assist DM1 patients on intensive insulin treatment.

Methods: A software application called Diab-Memory (based on Java 2 Mobile Edition) has been developed to support patients when entering diabetes-related data with synchronization to the remote database at the monitoring center. The data were then processed to generate statistics and trends, which were provided for the patient and his/her health care professional via a Web portal. The system has been evaluated in the course of a clinical before-after pilot trial. Outcome measures focused on patients' adherence to the therapy, availability of the monitoring system, and the effects on metabolic status. General user acceptance of the system was evaluated using a questionnaire.

Results: Ten patients (four female) with DM1 participated in the trial. Mean age was 36.6 years (± 11.0 years) and prestudy glycated hemoglobin (HbA_{1c}) was 7.9% (± 1.1%). A total of 3850 log-ins were registered during the 3 months of the study. The total number of received datasets was 13003, which equates to an average of 14 transmitted parameters per patient per day. The service was well accepted by the patients (no dropouts), and data transmission via mobile phone was successful on the first attempt in 96.5% of cases. Upon completion of the study, a statistically significant improvement in metabolic control was observed (HbA_{1c}: prestudy 7.9% ± 1.1% versus poststudy 7.5% ± 0.9%;*P*= .02). While there was a slight decrease in average blood glucose level (prestudy 141.8 mg/dL ± 22.5 mg/dL vs poststudy 141.2 mg/dL ± 23.1 mg/dL;*P*= .69), the difference was not statistically significant.

Conclusion: The results of the clinical pilot trial indicate that this proposed diabetes management system was well accepted by the patients and practical for daily usage. Thus, using the mobile phone as patient terminal seems to provide a ubiquitous, easy-to-use, and cost efficient solution for patient-centered data acquisition in the management of DM1. To confirm the promising results of the pilot trial further research has to be done to study long-term effects on glycemic control and cost-effectiveness.

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KEYWORDS

Telemedicine; diabetes mellitus type 1; blood glucose self-monitoring; mobile phone; Internet

Introduction

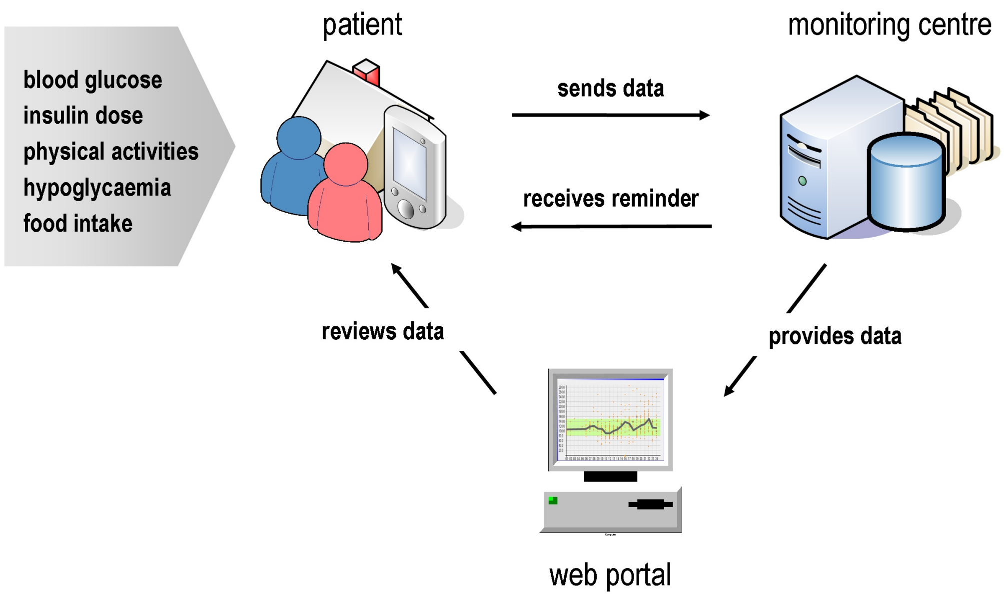
Self management of type 1 (insulin-dependent) diabetes mellitus (DM1) is essential to prevent acute and long-term complications [1]. Therefore, patients are trained in functional (intensive) insulin therapy (FIT) to independently control their blood glucose levels by multiple daily insulin injections [2].

To monitor important glycemic parameters and detect abnormalities at the earliest possible stage, patients are asked to carefully monitor their blood glucose levels and insulin doses. This information is used to help patients adjust their diabetes regimen.

Currently, paper-based diaries, PC programs [3], or Internet-based data services [4,5] are common. These diaries or services are not always available when needed, resulting in incomplete data and inaccurate data representations and feedback. This fact is often associated with poor compliance with therapy, suboptimal or poor glycemic control, and an increased risk of severe hypoglycemia with potentially serious consequences [6].

Nowadays, mobile phones and wireless Internet technology are advancing rapidly and are ubiquitously available at low cost [7]. Hence, mobile phones are poised to serve as the universal patient terminal in telemedicine scenarios and data services in the self-management of DM1 [8]. The basic idea presented in this paper is to provide the patient with an easy-to-use mobile phone–based diabetes diary, at low cost, to collect and to transmit daily key measurements to a remote monitoring center (Figure 1). Subsequently, the collected data are processed automatically, resulting in statistics and graphical data that are accessible to the patient via a Web portal.

Figure 1. Overview of the mobile phone–based diabetes self-management system



Several mobile phone–based approaches to support DM1 patients in their daily self- management have already been pursued using Short Message Service (SMS) text messaging [9-15], wireless Internet (WAP) [16,17], or Bluetooth functionality [18,19] of mobile phones. Mobile phones can be used for standard voice communication and transmission of a variety of multimedia information (text, audio, images, video), thus making them the patient terminal of choice for interactive communication and information exchange [20]. Data can be entered using the numeric keypad, or mobile phones can serve as a hub to enable wireless [18,19] or wired [21,22] data transfer from measurement devices (eg, blood glucose meter). The data are then forwarded to a central database via mobile Internet or text messaging.

The mobile phone can also provide an additional link between the health care professional and the patient for personalized feedback (eg, reminders, statistics, or medical advices) [9,10,14,16], education [12,13], or motivation [23]. In addition to technical feasibility, several studies have already pointed out the impact on adherence to therapy [11,12] and self-management

[10] when mobile phones are used. Reports of improved glycemic control are diverse. While some studies reported decreased glycated hemoglobin (HbA_{1c}) levels [12,15,16], others found no significant effects [11,17].

Differing results regarding improved glycemic control were also reported by large-scale review studies on telemedical intervention in diabetes management [24,25]. Hence, the authors recommended more research to study the impact of technical innovations on improved disease self-management, medical outcome, and cost-effectiveness.

The aim of the present study was to determine the feasibility and level of acceptance of a low-cost, mobile phone–based data service to support DM1 patients treated with FIT.

Methods

The mobile phone–based, patient-centered diabetes management system was built using state-of-the-art Internet technology and comprised the following:

1. *Patient terminal*: The mobile phone served as a patient terminal to support the patients in recording self-measurements, to trigger data transmission to the monitoring center, and to receive feedback via text messaging.
2. *Monitoring center*: A 24-hour accessible server system received, stored, and processed the data. Central components were user and data management to ensure security, integrity, and traceability of data. Role-based, hierarchical user management guaranteed that only authorized users were able to view, edit, or enter data.
3. *Graphical data representations and reminder*: An automated process analyzed incoming values in order to generate statistics, trends, and graphical representations of the data. In response to the incoming data, reminder messages were generated and sent to patients' mobile phones using text messaging.
4. *Web portal*: Data were accessible by patients and health care professionals using a standard Web browser.

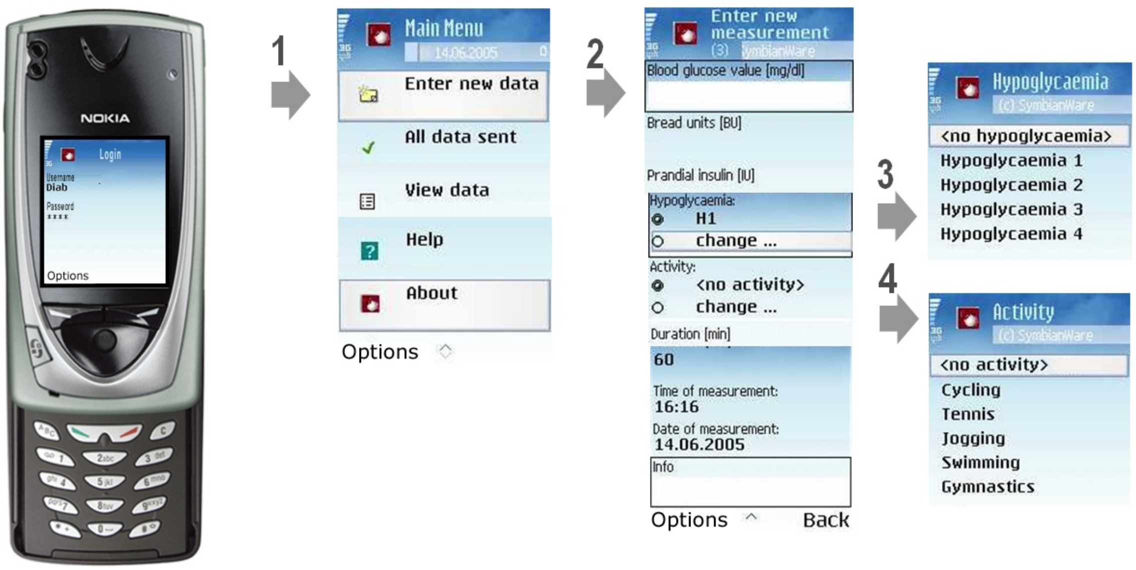
Mobile Phone–Based Patient Terminal

A software application called Diab-Memory, based on Java 2 Mobile Edition (J2ME), was developed to support the patients in entering diabetes-related data: (1) blood glucose level, (2) injected insulin doses, (3) content of carbohydrates in meals, (4) well-being, and (5) physical activities. Data were remotely synchronized to the database at the central monitoring center. The graphical user interface is shown in Figure 2.

After logging in, the patient was guided through the data acquisition process. The data were entered manually using the alphanumeric keypad of the mobile phone. The Diab-Memory software application provided an appealing user interface by using metaphoric elements. The patient was guided through the data acquisition process: (1) user authentication, (2) data entry (eg, blood glucose, content of carbohydrates in meals, insulin dose), (3) hypoglycemia classification if appropriate (1 to 4), and (4) physical activity if performed (eg, tennis, jogging).

To decrease error rate, entered values were immediately checked for plausibility. In case of values above or below predefined thresholds, the patient was warned and asked to enter data again before the data were stored into a database on the mobile phone. The patient could transmit the values immediately or initialize the synchronization process at a later time via mobile Internet-based data transfer using the General Packet Radio Service (GPRS).

Figure 2. Diab-Memory interface on the mobile phone



Web Portal

The Web portal allows authorized users to access the data via a PC and Internet browser. The graphical user interface components provided the user with a quick overview and supported straightforward navigation. Transmitted values could be accessed easily by the diabetes data template (Figure 3). The patients were also able to enter data using this template. By clicking on the appropriate box in the matrix (hour x, parameter y), a data input window appeared in which the relevant parameter could be entered. Data editing was also possible in the same way.

Figure 3. The diabetes data template

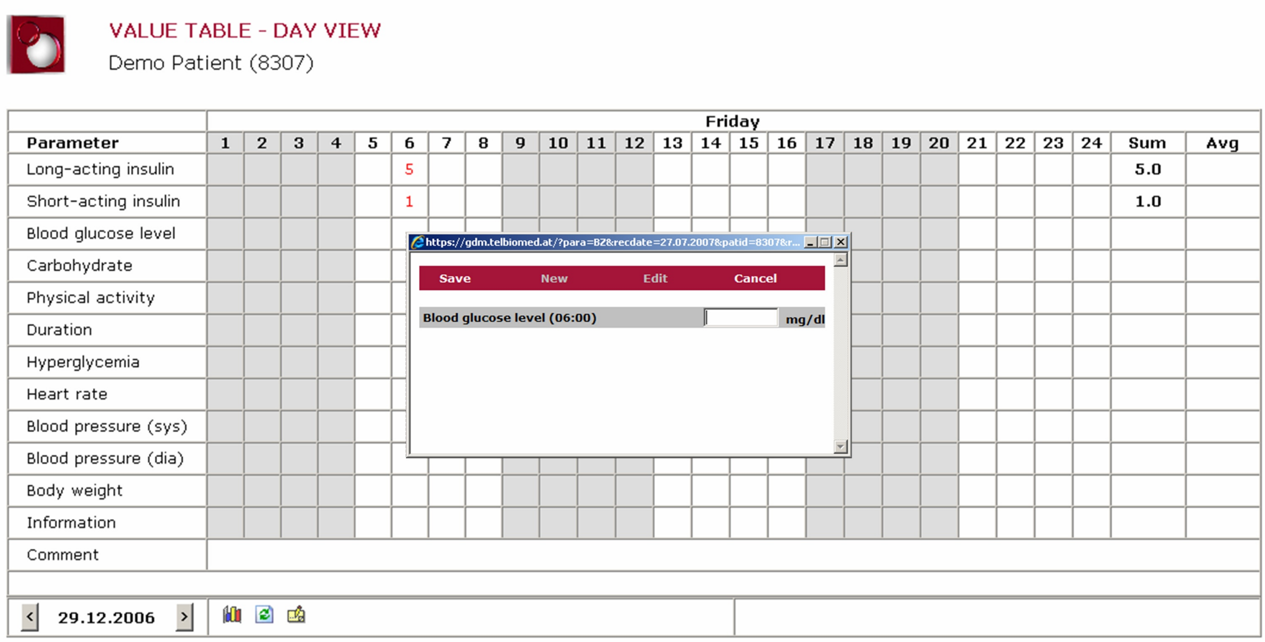
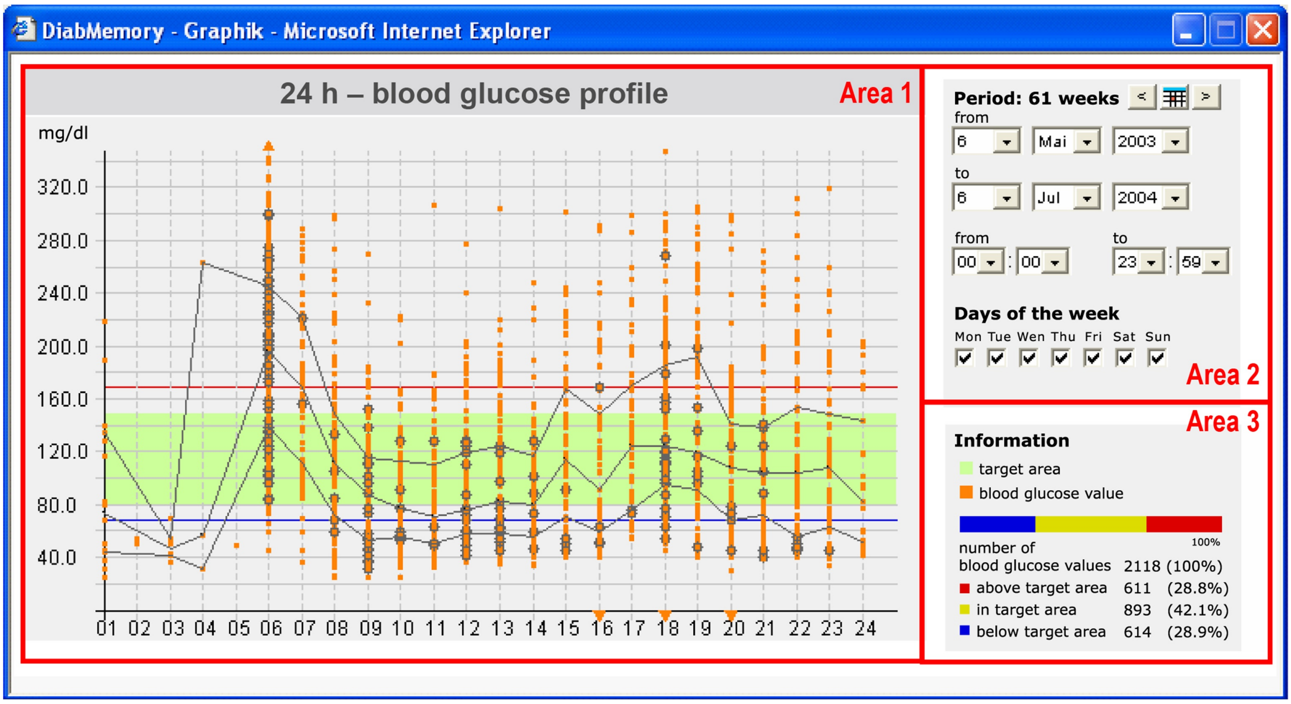


Figure 4. Graphical representation of patient blood glucose data



Statistics and graphical representations of the transmitted data were accessible via Web portal using a JAVA applet (Figure 4). The applet was executed in a pop-up window. First, all available datasets corresponding to a given patient were automatically downloaded to the browser. Thereafter, the user was able to quickly navigate through the datasets without the need for further data download.

A typical 24-hour blood glucose profile is shown in area 1 of Figure 4. The green band indicates the target blood glucose level (80 mg/dL to 150 mg/dL). In addition, the median, upper/lower quartile, and individual upper (red line) and lower (blue line) alert levels are displayed. Transmitted blood glucose measurements were assigned to the corresponding time of day (hour 1-24) and are shown as orange spots. The user was able to navigate through the data by using time navigation (area 2). A summary of the presented data is given as a bar chart in area 3. The blue bar indicates the number of blood glucose values below the target level, and the red bar indicates the number of blood glucose values above the target level. The number of blood glucose values within the target range is represented by the yellow bar.

Clinical Evaluation

The developed diabetes management system was evaluated in the course of a clinical trial that had been approved by the ethics committee of the Medical University of Vienna (EK 485/03, January 13, 2003). Inclusion criteria were diagnosis of DM1, poor adherence to FIT resulting in suboptimal or poor glycemic control with a lower HbA_{1c} value > 7.5%, age 18-80 years, and the ability to operate a mobile phone. Patients with implanted pacemakers or cardioverter defibrillators were excluded from the study.

Ten adults with DM1 agreed to participate in the trial. After signing the informed consent document, the patients were registered to the service and received a secure username/password combination to access the service via the mobile phone or Web portal. The patients were equipped with a mobile phone (Nokia 7650, Nokia, Finland) with the Diab-Memory software application pre-installed and a step-by-step manual.

The patients were instructed to track daily blood glucose measurements and to register the following using the mobile phone: injected basal and bolus insulin doses, content of carbohydrates in meals (1 carbohydrate [bread] unit equals 12 g of glucose), physical activities, and symptoms of hypoglycemia. In cases of less than three successful data transmissions per day, an automatic reminder message was sent to the patient's phone via SMS. Although the physician could assess the data via Web portal, medical intervention was not planned. During the study, a help desk was established at the monitoring center. Skilled personnel handled questions from users and were responsible for training.

At the end of the 3-month study period, the patients were reviewed in the diabetes clinic and their $HbA_{1c}$was checked. To assess patient satisfaction with the system, the patients were asked to fill in a questionnaire.

Data Analysis and Statistical Methods

Primary outcome measures were patients' adherence to FIT, overall availability of the monitoring system, general user acceptance, and usability. We expected that more than 75% of prescheduled measurements would be performed and transmitted to the monitoring center, less than 25% of participants would drop out due to any reason, and the availability of the system would be at least 95%.

Baseline statistics and frequencies of data transmissions and the received data were calculated by standard statistical methods using R statistical software, version 2.4.1 (R Foundation for Statistical Computing, Vienna, Austria) [26]. To assess usability of and patient satisfaction with the system, the cumulative monitoring period, the cumulative transfer sessions, and the total number of received parameters were calculated.

Cumulative monitoring periodis the sum of the number of days from the first to the last successful data transmission for all participants. Cumulative transfer sessions indicate the overall number of datasets transmitted successfully to the monitoring center. Cumulative received parameters add up the number of individual parameter values as entered, transmitted, and received during the cumulative monitoring period.

The secondary endpoint of the study was the impact on glycemic control. HbA_{1c}values were therefore measured at the beginning and end of the study period. Additionally, averaged blood glucose levels from the first 14 days of the study period were compared to blood glucose levels of the last 14 days of the study period. The significance of pre- and post-monitoring differences were assessed using the Wilcoxon signed rank test for paired data.

Results

Table 1 summarizes patient characteristics and monitoring results. Ten patients (four females) with DM1 participated in the trial. Mean age was 36.6 years (± 11.0 years). During the 3 months of the study, a total of 3850 log-ins (3478 via mobile phone and 372 via Web portal) were registered. The total number of received values was 13003 (1300 ± 315 per patient), corresponding to an average of 14 transmitted parameters per patient per day. Data transmission via mobile phone was successful on the first attempt in 96.5% of cases. The availability of the system was 98%.

There were no dropouts during the study period. On 780 out of 920 cumulative monitoring days, at least three blood glucose values were sent, which indicates an adherence rate of 85%. There were 294 (29 ± 23 per patient) SMS reminders sent in the evening. An SMS reminder was sent if less than three blood glucose measurements had been received that day.

Table 1. Patient characteristics and monitoring results

	Total	Mean (SD)	Percentage
Total number of patients	10		
Female patients	4		
Dropouts	0		
Age, years		36.6(11.0)	
Cumulative monitoring period, days	920	92 (0)	100
Cumulative monitoring days where > 3 blood glucose measurements were received	780	78 (18)	84.8
Number of SMS reminders	294	29 (23)	
Data corrections via Web interface	183	18 (22)	
Cumulative transfer sessions	3850		100
Log-in via mobile phone	3478		90.34
Log-in via desktop PC	372		9.66
Cumulative received parameters	13003	1300 (315)	100
Blood glucose, mg/dL	4294	429 (121)	33.02
Basal insulin dose rate, insulin unit	1414	141 (47)	10.87
Bolus insulin dose rate, insulin unit	3686	369 (120)	28.35
Carbohydrate units, bread unit	3368	337 (83)	25.90
Hypoglycemia	241	24 (25)	1.85

All 10 participants were asked to answer questions (Table 2) at the end of the trial. Seven patients returned completed questionnaires. They reported that they already had experience using a mobile phone and that the Diab-Memory software application was easy to learn and easy to use. They stated that the navigation and the data entry were practical for regular daily use. Problems in reading the display were not reported.

The data acquisition procedure, including blood glucose measurements, log-in, data entry, and data transmission took an average of 3 minutes. Six out of seven patients had already used a hand-written or PC-based diabetes diary. All patients agreed that they found the service helpful. Five out of seven patients responded that an additional teleconsultation with the responsible health care professional at the hospital based on tracked values would be desirable.

Table 2. Patient questionnaire (translated from German) on the diabetes management service (n = 7)

Q1	Have you used a mobile phone prior to this study?	yes: 7	no: 0	
Q2	Was the display legible?	yes: 7	no: 0	
Q3	Did you experience problems while inputting data?	yes: 2	no: 5	
Q4	Was the menu prompt easy to navigate?	easy: 5	fair: 2	
Q5	Amount of time required for data entry (on average):	< 2 minutes: 3	> 2 minutes: 4	
Q6	Have you used mobile Internet services for mobile phones prior to this study?	yes: 3	no: 4	
Q7	Length of your training period:	one day: 6	several days: 1	
Q8	Did you send data immediately after measurement?	yes: 2	no: 5	
Q9	Before this study, did you record diabetes-related data at regular intervals?	yes: 6	no: 1	
Q10	Did you use a diary to record your data?	paper-based: 4	electronic: 2	
Q11	How often were your data examined by the responsible physician?	monthly: 1	once every 3 month: 6	
Q12	Length of time spent in doctor's office per visit:	1-2 hour: 1	2-3 hours: 2	3-4 hours: 4
Q13	Amount of money spent on diabetes-related medication/equipment per month:	€0: 0	< €25: 5	€25-50: 2
Q14	Do you think that the electronic patient diary is a good concept?	very good: 6	good: 1	unusable: 0
Q15	Would you recommend this service to other patients?	yes: 6	no: 1	
Q16	Would you like to continue to use this service?	yes: 4	no: 2	
Q17	Would you use this service even if you have to pay for it?	yes: 4	no: 3	
Q18	If yes, how much would you spend on this service?	< €5: 1	€5-10: 2	
Q19	Do you have Internet access at home?	yes: 6	no: 1	
Q20	Do you find the "up-to-date trend charts" and "statistics" useful?	yes: 5	no: 2	
Q21	Did you inform your colleagues and/or friends about the service?	yes: 5	no: 2	
Q22	Would you like your physician to be more involved?	yes: 5	no: 2	
Q23	Did you discuss this service with your family doctor? His/her first impression was…	positive: 2	sceptic: 0	
Q24	Additional comments			
	I found it very useful to store the data on the mobile phone and to transmit the summarized data once a day.			
	I'm afraid that the doctor-patient relationship will get lost when I'm using this system.			

Regarding the clinical outcome, we found a statistically significant decrease in HbA_{1c}(7.9% ± 1.1% vs 7.5% ± 0.9%;*P*= .02) and a slight but not statistically significant decrease in average blood glucose level (141.8 mg/dL ± 22.5 mg/dL vs 141.2 mg/dL ± 23.1 mg/dL;*P*= .69).

When data from the first 2 weeks of the study were compared to data from the last 2 weeks of the study period, the following trends were observed, but all remained not statistically significant: The number of blood glucose measurements above the 150 mg/dL threshold decreased (39.9% to 37.7%;*P*= .07), the number in the normal range decreased (43.1% to 42.0%;*P*= .13), and the number of blood glucose measurements below the 80 mg/dL threshold increased from 17.0% to 20.3% (*P*= .82).

Table 3 summarizes and compares metabolic control during the first and the last 2 weeks of the study period.

Table 3. Metabolic control: comparing the first and last 2 weeks of the study period

	Before the Study	After the Study	*P* Value
HbA_{1c}, mean (SD)	7.9% (1.1%)	7.5% (0.9%)	.02
	First 2 Weeks of Study	**Last 2 Weeks of Study**	
Blood glucose, mean (SD)	141.8 mg/dL (22.5 mg/dL	141.2 mg/dL (23.1 mg/dL	.69
Number of reported hypoglycemia values, mean (SD)	4 (5.9)	3 (3.9)	
Total number of blood glucose measurements transmitted (%)	725 (100%)	595 (100%)	
Above 150 mg/dL threshold	289 (39.9%)	224 (37.7%)	.07
In normal range (80-150 mg/dL)	313 (43.1%)	250 (42.0%)	.13
Below 80 mg/dL threshold	123 (17.0%)	121 (20.3%)	.82

Figure 5 shows the graphical representation of typical 24-hour blood glucose profiles from three patients who participated in the trial. Patient 1 showed a stable condition, in the sense that about 87% of the blood glucose measurements were within the target range of 80 mg/dL to 150 mg/dL. Patient 2 showed increased blood glucose levels in the morning, whereas the blood glucose level in the afternoon was under control. Patient 3 showed poor glycemic control in the morning and the evening. Table 4 adds characteristic values for the same three patients.

Figure 5. Visualization of the 24-hour blood glucose profiles of three participants

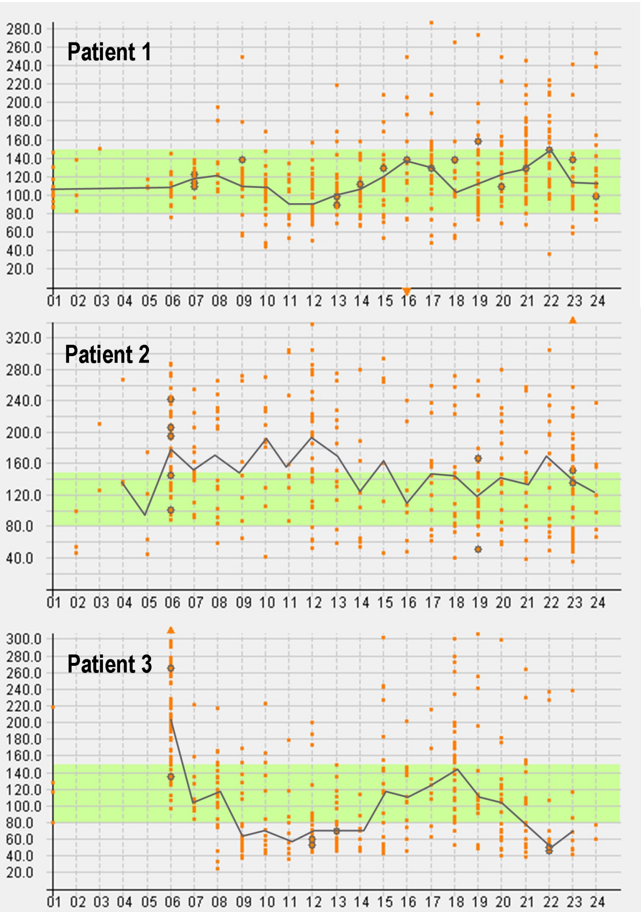


Table 4. Characteristics of three participants (corresponding 24-hour blood glucose profiles appear in Figure 5)

	Patient 1	Patient 2	Patient 3
Gender	female	male	male
Age (years)	35	30	47
Total number of blood glucose measurements transmitted (%)	469 (100%)	325 (100%)	351 (100%)
Above 150 mg/dL threshold	42 (9%)	127 (39%)	74 (21%)
In normal range (80-150 mg/dL)	408 (87%)	163 (50%)	180 (51%)
Below 80 mg/dL threshold	19 (4%)	35 (11%)	97 (28%)

Discussion

This paper assessed the technical feasibility and usability of a Web-based data service for DM1 patients using a mobile phone as the patient terminal. The system was evaluated in the course of a clinical pilot study, indicating broad acceptance and significant improvement in metabolic control.

Rapid advancements in information and communication technologies open new possibilities for improved DM1 therapy management. In recent years, several mobile and Web-based telemedicine applications have been developed in order to support diabetes patient self-management. Reviewing the literature, telemedicine services in diabetes care are feasible and acceptable, but evidence of improved glycemic control is weak [24,25,27]. This may be due to poor adherence of patients to the therapy regimen and/or refusal to use telemedicine equipment on a regular basis in day-to-day-care [17]. Because of the ready availability of mobile phones and the possibility of using mobile phones for standard communication issues as well, these devices may serve as patient terminals for health data acquisition in many future telemedicine scenarios.

Feasibility (Primary Endpoint)

The results of the study have shown that a J2ME-based software application running on widely available off-the-shelf mobile phones provides a robust, easy-to-use, and secure platform for interacting with the diabetes management system. The results of our pilot trial have indicated a high success rate of data transmission (96.5%). In only 3.5% of the cases, a log-in to the service was recognized but data transmission failed, most likely due to a lack of GPRS network connectivity. Since the data are stored in a database on the mobile phone, the transmission could be postponed until network connectivity again became available.

The J2ME software application allows improved usability through the design of user-friendly graphical user interfaces. It uses metaphoric elements and provides data entry plausibility checks. Errors can therefore be excluded at origin, leading to a low error rate. The results show that only 1.4% (183/13003) of cases required correction of the transmitted value via the Web portal (see Table 1). User acceptance was 100%, as indicated by the fact that there were no dropouts and two patients chose to continue using the service even after the study had been closed.

Two participants reported technical problems during the study. One patient complained of a keypad malfunction, and the other reported permanent connection problems due to lack of GPRS network connectivity at home.

Both problems were solved: in the first case, the mobile phone was replaced, and in the second case, the patient was asked to postpone data transmission until entering an area of acceptable network connectivity.

Although the patients also had the option of using a Web portal for data input, over 90% of values were transmitted via mobile phone. The remaining 10% of values were entered via the Web portal mainly by two patients who used the Internet access at their work. User activities via the Web portal were not analyzed in detail as it was not within the scope of the study. The availability of the system was 98%, which means that patient data transfer was almost always possible during the entire study period.

Five out of seven patients rated visualization and up-to-date statistics as very helpful for self-management and monitoring. It was seen as useful to navigate through the data over time in order to make changes in glycemic control visible. This could be convenient in the case of therapy or lifestyle changes to allow early identification of illness patterns. Two participants felt overwhelmed with self-interpretation of the data and stated that it would be more helpful to have direct feedback from the health care professional. In those cases, interactive representation of data can provide a basis for the health care professional to derive medical advice or instructions.

Effective management of chronic disease requires a close partnership between the patient and health care professional, which can be supported by contemporary information and communication technologies. Telemedical data services are not intended to replace patient-physician contact but rather to assist the patient in diabetes self-management. We propose an individual therapy schedule for each patient. Efficient therapy management alternates telemedical interventions and clinic visits depending on the health status and independence level of the patient.

Individual Metabolic Status (Secondary Endpoint)

Aside from simplification and increased efficiency of documentation, the system was able to improve patients' adherence to the treatment scheme. We expected that more than 75% of prescheduled measurements (at least three blood glucose measurements daily) would be performed and transmitted to the monitoring center. The results indicated a therapy adherence rate of 85%, and most likely as a consequence of improved adherence, a significant improvement in HbA_{1c} and a decreased number of overshoots of the 150 mg/dL blood glucose threshold.

The observed positive effects may have been influenced by the small sample size and the fact that patients where selected neither randomly nor consecutively. We cannot exclude the possibility that subjects who subscribed to the study had an enthusiasm for technical innovations and good therapeutic compliance. The small sample size is also unlikely to represent all patients with DM1, which may influence the robustness of the results.

During the study period, there was no interaction between the health care professional and the patient. Patients who transmitted less than three successful blood glucose measurements were automatically sent a reminder message to their mobile phone. This feature may also have contributed to improved quality of self-managed therapy.

Operating the Monitoring Center

Because of the limited number of users and expected workload, neither specific hardware components nor particular server architecture were considered. In order to guarantee almost 100% availability of the monitoring center, hosting issues and maintenance of technical equipment and software had to be addressed.

Additionally, a help desk was established during the study. The help desk was accessible via telephone or email. Skilled personnel handled questions and were responsible for training subjects after registration. Initial training took place by telephone and took approximately 20 minutes. Participants were introduced to the use of the software on the mobile phone and the Web portal. Patients were then asked to explore the functionality of the system independently. Data from the initial day were therefore not used for further analyses. Six out of seven patients were able to operate the service after one day; only one participant needed additional training. Hence, frequency of help desk assistance for technical issues was low.

Costs

Patients incurred no costs during the pilot trial. The mobile phone was provided with a free data bundle and the Diab-Memory service. There were also no clinic costs as the health care professional was not involved in therapy management during the study. For further large-scale telemonitoring scenarios, costs to patient, service, and clinic have to be considered.

As network providers offer a wide range of packages and fees, including or excluding data bundles, costs to the patients are difficult to estimate. However, assuming that the patient already owns a mobile phone and the contract includes a data bundle, an extension would not be necessary because the amount of data for Diab-Memory is marginal. If a data bundle is not included, the required upgrade would cost about €10 per month.

The costs of the service and the health care professional are also difficult to assess. The operating costs depend on the number of users and complexity of the service, while costs for the health care professional are dependent on time spent on monitoring. To reduce labor costs, automatic data analysis and alerts for the physician would be helpful in case of detected abnormalities.

Aside from improved medical care through patient empowerment, it is predicted that home monitoring would be cost-effective. The idea of home monitoring is to guide the patient to the best possible health outcomes and to identify problems at the earliest possible stage. Hence, long-term complications and emergencies could be avoided, resulting in reduced costs from clinic visits. This may free financial resources of clinics. However, these processes are very complex, involve many stakeholders (and financial investors), and differ between health care systems. To study pecuniary effects of telemedical data services in DM1, further research and large-scale studies are needed.

Future Developments

The promising results from the present pilot study will lead to further innovations to improve the diabetes management system in near future. These are related to data acquisition, automatic feedback and alerts, and communication between patient and health care professional.

Data Acquisition

Although the Diab-Memory software was well accepted, an automated method to assess the measurements would be helpful. Running J2ME-based software applications on mobile phones will support access to integrated mobile phone features like Bluetooth and Infrared technology. This technology could be used to transfer data from the glucose meter to the mobile phone automatically. Several studies have already highlighted the technical feasibility of blood glucose meters supporting automatic data transfer. However, for effective diabetes management, further relevant data, including insulin doses and physical activity, are required. At the moment, these data have to be added manually using a numeric keypad. A promising solution could be the use of near field communication (NFC) in telemonitoring scenarios. Near field communication supports a touch-based method for data acquisition using the mobile phone [28], and, in addition to allowing the capture of readings from a meter, it provides access to data stored on radio frequency identification (RFID) tags (eg, electronic barcodes), which could be embedded in future diabetes care monitoring scenarios.

Automatic Feedback and Alerts

The present study showed the feasibility of reminder messages sent via SMS to the patient. Future studies should evaluate whether close monitoring of therapy parameters combined with automatically generated feedback and instructions can further improve the metabolic control of patients with DM1. To facilitate this, automated analysis and rule-based interpretation of transmitted data on an individual basis would be helpful.

Communication

The study revealed the need for teleconsultation between the patient and the health care professional regarding the blood glucose data provided. One patient stated that he would be afraid to lose personal contact with the physician if using this system. Hence, the Web portal must provide a collaboration and communication platform between the patients and their health care professionals in order to allow an additional link between these partners.

Conclusion

The prototype was designed to demonstrate feasibility, to evaluate user needs, and to help us understand the complex processes of DM1 self-management. The results of the present study indicate that diabetes management based on mobile phones and the Internet is technically valid and well accepted by patients for daily use and resulted in improved glycemic control. Thus, using mobile phones as patient terminals seems to provide a ubiquitous and easy-to-use solution for patient-centered data acquisition in the management of DM1. The results and the recommendations for improvement provide the basis for further research. To confirm the promising results of the pilot trial, further research must be done to study long-term effects on glycemic control and cost-effectiveness. In the next step, a randomized trial must be carried out with a larger sample size and physician involvement.

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Conflicts of Interest

None declared.

Authors' Contributions

Alexander Kollmann and Michaela Riedl contributed equally to the paper.

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Original Paper

Pragmatists, Positive Communicators, and Shy Enthusiasts: Three Viewpoints on Web Conferencing in Health Sciences Education

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Abstract

Background: Web conferencing is a synchronous technology that allows coordinated online audio and visual interactions with learners logged in to a central server. Recently, its use has grown rapidly in academia, while research on its use has not kept up. Conferencing systems typically facilitate communication and support for multiple presenters in different locations. A paucity of research has evaluated synchronous Web conferencing in health sciences education.

Objective: McMaster University Faculty of Health Sciences trialed Wimba's Live Classroom Web conferencing technology to support education and curriculum activities with students and faculty. The purpose of this study was to explore faculty, staff, and student perceptions of Web conferencing as a support for teaching and learning in health sciences. The Live Classroom technology provided features including real-time VoIP audio, an interactive whiteboard, text chat, PowerPoint slide sharing, application sharing, and archiving of live conferences to support student education and curriculum activities.

Methods: Q-methodology was used to identify unique and common viewpoints of participants who had exposure to Web conferencing to support educational applications during the trial evaluation period. This methodology is particularly useful for research on human perceptions and interpersonal relationships to identify groups of participants with different perceptions. It mixes qualitative and quantitative methods. In a Q-methodology study, the goal is to uncover different patterns of thought rather than their numerical distribution among the larger population.

Results: A total of 36 people participated in the study, including medical residents (14), nursing graduate students (11), health sciences faculty (9), and health sciences staff (2). Three unique viewpoints were identified: pragmatists (factor 1), positive communicators (factor 2A), and shy enthusiasts (factor 2B). These factors explained 28% (factor 1) and 11% (factor 2) of the total variance, respectively. The majority of respondents were pragmatists (n = 26), who endorsed the value of Web conferencing yet identified that technical and ease-of-use problems could jeopardize its use. Positive communicators (N = 4) enjoyed technology and felt that Web conferencing could facilitate communication in a variety of contexts. Shy enthusiasts (N = 4) were also positive and comfortable with the technology but differed in that they preferred communicating from a distance rather than face-to-face. Common viewpoints were held by all groups: they found Web conferencing to be superior to audio conferencing alone, felt more training would be useful, and had no concerns that Web conferencing would hamper their interactivity with remote participants or that students accustomed to face-to-face learning would not enjoy Web conferencing.

Conclusions: Overall, all participants, including pragmatists who were more cautious about the technology, viewed Web conferencing as an enabler, especially when face-to-face meetings were not possible. Adequate technical support and training need to be provided for successful ongoing implementation of Web conferencing.

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KEYWORDS

Web conferencing; Q-methodology; synchronous communication; e-learning; distance education; Internet

Introduction

Synchronous Conferencing Technologies and e-Learning

There has been increasing investment in the application of e-learning technologies in Canadian educational institutions. Yet a recent review of e-learning research in Canada indicated that the majority of the research appears to have focused on distance education, with less attention placed on hybrid/blended (mixed online and face-to-face) learning contexts. Findings from their review of post secondary education research showed that the appropriate use of computer-mediated education can enrich the learning environment, reduce isolation, and increase motivation for distance learners [1].

Due to the expansion of multi-site and collaborative undergraduate and graduate programs, the struggle to meet the needs of students who are juggling work and school, and the growing demands for an increased health professional workforce in Canada [2], health sciences education programs are challenged to find effective ways to reach learners in real time. Web conferencing trends continue to escalate to support collaborative work in industry [3] as well as education [4,5]. Educational applications have moved beyond classroom work to include support for administrative meetings, interviews, and even Web casts of commencement ceremonies [6]. As applications of synchronous (real-time) technologies to support colleges and universities have grown, the research on their use has not kept up. Although much has been written about the use of e-learning to support health sciences education, a review of e-learning practices in undergraduate medical education found few reported studies on the use of synchronous communication technologies [7].

Videoconferencing Versus Web Conferencing

Videoconferencing and Web conferencing are both synchronous communication technologies. A videoconferencing system allows people in different locations to interact via video and audio, most frequently with dedicated video and telephone equipment set up in a special-purpose room—often due to the requirement of special cameras, microphones, and dedicated telephone lines (eg, T1 or ISDN). Thus, videoconferencing often requires that participants travel to designated conferencing sites to connect to other remote sites. In contrast with older videoconferencing systems' dependence on analog signals and telephone equipment, Web conferencing enables collaborative interaction using voice over Internet protocol (VoIP) communication between a network of computers, which can share images, presentations, and computer applications, connecting from desktop computers in remote locations [6]. Many Web conferencing systems support the streaming of video as well as audio and presentation images. Improvements in streaming technologies and bandwidth have contributed to the growth of Web conferencing.

Synchronous Conferencing Technologies in Health Sciences Education

Such synchronous conferencing technologies have been used to support health sciences education; however, most evaluations report their use in continuing education and graduate programs. Gagliardi et al [8] conducted a pilot study in which community-based surgeons used videoconferencing to support multidisciplinary oncology rounds. Participants completed surveys which showed that they generally felt positive about the videoconferencing, and the authors concluded that it is possible to engage participants remotely through videoconferencing. Odell et al [9] assessed the feasibility of using videoconferencing to support dental postgraduate education in the United Kingdom. Teachers completed surveys immediately after conferences and participated in a follow-up interview 1 week after each conferencing session; 27 teachers involved in 41 sessions were included in the sample. Most teachers preferred videoconferencing to on-site teaching due to savings in travel time; however, they also experienced a sense of distance with the audience and had difficulties managing question and answer periods. Training was felt to be essential for successful videoconferencing.

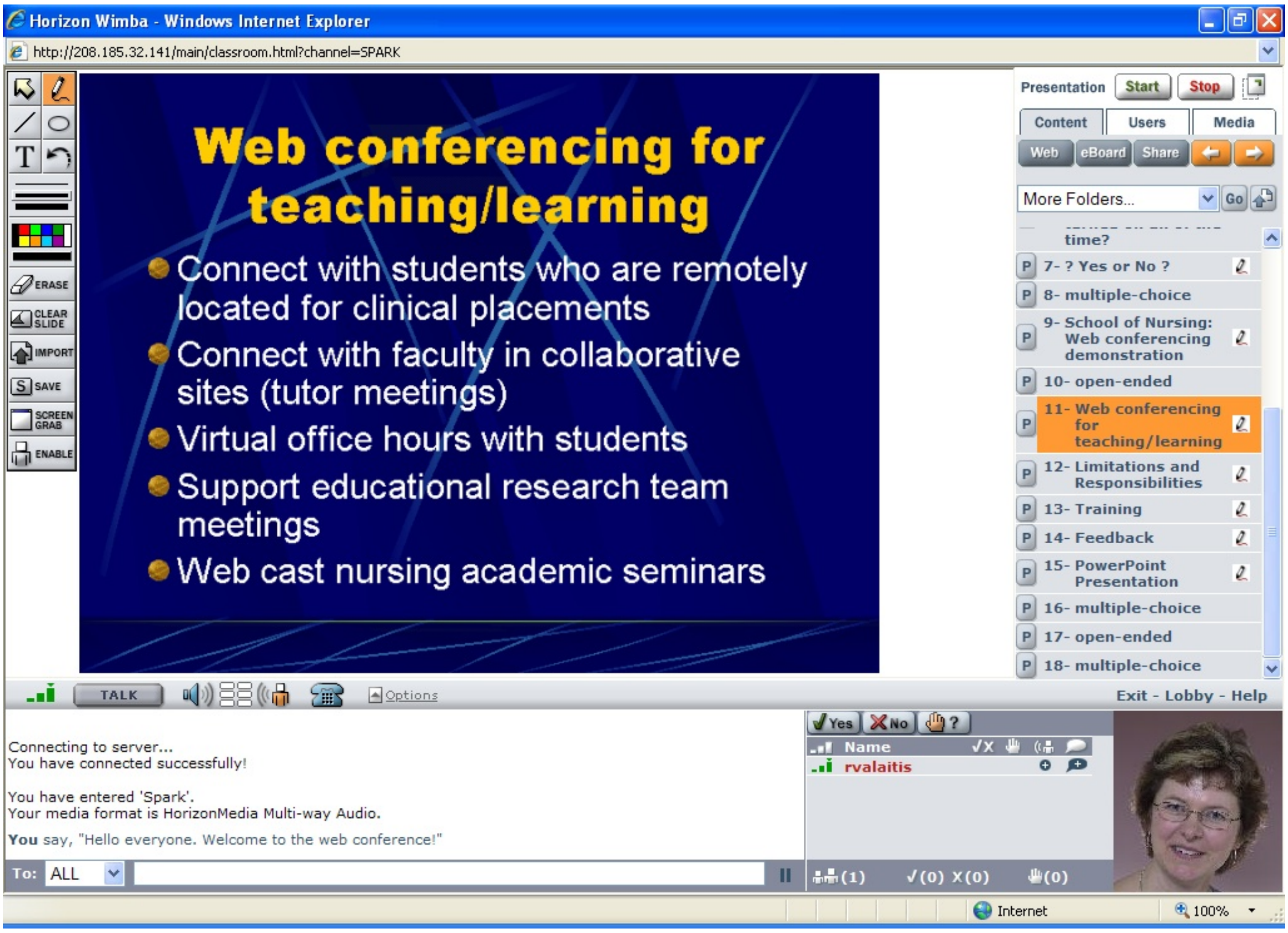
Locatis and colleagues [10] evaluated a mix of videoconferencing, Web casting, and chat technology delivered over the Internet to engage health professionals in a conference. They found that although it was technically feasible to deliver a live Web cast with additional chat facilities, difficulties with latency of audio and visual displays were problematic. Up to 2-minute delays created significant synchronous communication problems, which were felt to be related to differences in streaming formats. Participants were also unfamiliar with viewing a table of images from multiple sites compared to a typical single image broadcast. Connection problems were also experienced due to issues with firewalls, bandwidth limitations, and local network configurations.

We found a general paucity of research that evaluated Web conferencing in health sciences education. The research was generally found in white papers, and peer-reviewed papers were limited to reports of experiences and/or results from satisfaction surveys. An evaluation of Web conferencing by public health professionals who participated in monthly development sessions on emergency preparedness indicated that technical problems decreased quickly after a single experience with the technology [11]. Web casting using Mediasite (Sonic Foundry, Inc) was evaluated as a tool to support a graduate nursing program [12]. Mediasite can broadcast video streams of the lecturer as well as push presentation images from the presenter's computer. Polls, question-and-answer, and text chat features were used to promote communication. Students' evaluations (N = 27) indicated that most connected from home and used broadband access. The quality of the broadcast diminished with dial-up connections. Overall, participants were satisfied with the technology and their interaction with the instructor and appreciated the cost savings resulting from decreased travel time. However, some participants missed the human interaction while online. Ostrow and DiMaria-Ghalili [13] reported on 20 years' of experience in delivering graduate nursing education by distance, which most recently included Web casting. They described lessons learned from their experiences, including the need for a solid orientation to the technology, reliable easy-to-use technology with technical support available 24/7, the provision of prompt and highly responsive feedback to students, and institutional partnerships to support students. They noted that mature students who started the program with little technical savvy left with highly improved technical skills. They felt that the use of technology increased student recruitment and enrollment and program cost-effectiveness.

In addition to supporting health sciences education, Web conferencing has been used with success to support a health sciences research "collaboratory" [14]. The collaboratory involved an oral cancer center and an HIV/AIDS center in the United States; virtual meetings were supported using Web conferencing technologies (NetMeeting, Placeware). The virtual meetings aided communication on the initiation of joint studies and data analysis. Over time, larger group meetings became less frequent and more one-on-one, cross-site meetings occurred between researchers. Well-attended webinars (PlaceWare and conference calls) were used to broadcast presentations of pre-publication data among involved research centers.

In 2005, McMaster's Faculty of Health Sciences trialed the use of Web conferencing technology with students, administrative staff, and faculty of undergraduate and graduate programs in medicine, midwifery, nursing, and rehabilitation sciences. Wimba Inc's Live Classroom technology was used, which provided features including real-time VoIP audio, an interactive whiteboard, text chat, PowerPoint slide sharing, application sharing, and archiving of live conferences to support student education and curriculum activities (Figure 1).

Figure 1. Screen capture of Web conferencing interface of Live Classroom



It was timely to examine student, staff, and faculty views on the use of Web conferencing since use of this technology has continued to grow [6] and has the potential to address problems in evermore complex and expanding health sciences education programs. It is critical to explore instructor, staff, and learner viewpoints during the initial application of a learning innovation to inform uptake and acceptability of the technology. The purpose of this study was, therefore, to investigate faculty, student, and support staff perceptions of the use of Web conferencing as a support for teaching and learning in health sciences using Q-methodology. This paper also demonstrates the unique contribution of the use of Q-methodology in health sciences educational research, which capitalizes on the benefits of qualitative and quantitative approaches.

Methods

Sampling and Recruitment

Faculty, staff, and students in the Faculty of Health Sciences who participated in one or more Web conferences from August

2005 to January 2006 were asked to take part in the evaluation. During this time, Web conferencing was used to support weekly graduate nursing seminars, academic rounds for medical residents, and faculty meetings with faculty located at multiple sites. The first author oversaw the administration of Web conferencing technology in the Faculty of Health Sciences during this phase. Faculty who booked use of the technology over this time frame were invited to participate in the study. All faculty and staff who had booked a Web conference during the trial period were asked to forward an email invitation for the study to their students and faculty who had participated in a Web conference. A nonrandom convenience sample of participants was approached, including (1) an anesthesiologist and his residents; (2) graduate students in nursing, graduate nursing faculty, administrative staff, and guest presenters who were involved in weekly graduate seminars; and (3) faculty members of the Nursing Information and Communication Technology Committee who taught in the undergraduate nursing program. Groups who attended a data collection meeting to complete the Q-sort exercise received refreshments; in addition, every participant also received a Can $5 coffee shop gift certificate. Ethics approval was received for the study from the McMaster University Research Ethics Board.

Q-Methodology

Q-Methodology was used to identify common viewpoints of students, faculty, and administrative staff who had exposure to Web conferencing. This method has been used in different aspects of health sciences research, including evaluation of job satisfaction [15], patients' viewpoints on health and rehabilitation [16], use of research information in clinical decision making [17-19], and exploration of nursing attitudes toward health promotion [20]. Many educational studies seek to understand satisfaction and perceived usefulness of different educational strategies by educators and students, hence our desire to also employ this method and receive feedback on its feasibility and effectiveness.

Q-methodology was introduced in 1935 by Stephenson [21,22] and was only employed sporadically until recently emerging as a more widely used method, mainly because of advances in the statistical analysis component [22]. This method is used to identify unique viewpoints as well as commonly shared views, and it is particularly valuable in research that explores human perceptions and interpersonal relationships [15]. The method allows the researcher to identify groups of participants having similar and alternate viewpoints, and, in turn, to ascertain similarities and differences between groups. It mixes qualitative and quantitative methods. In a Q-methodology study, the goal is to uncover different patterns of thought rather than their numerical distribution among the larger population. In other words, the number of participants is not the important issue; rather, it is the representation of different points of view about the topic of study [23]. Q-studies typically use small sample sizes compared to, for example, survey research, and low response rates do not bias the results because the primary objective is to identify a typology, not to test the typology's proportional distribution within the larger population [24]. Brown [25] recommends that 40-60 participants are more than adequate for most studies, and far fewer may be needed for some specific studies. He maintains that "what is of interest ultimately are the factors with at least four or five persons defining each; beyond that, additional subjects add very little." Therefore, a factor with at least four subjects and an eigenvalue greater than one would be considered a significant factor. In this study, we approached approximately 50 individuals who had exposure to Web conferencing during the trial period.

Q-methodology uses correlation and by-person factor analysis (ie, the statistical analysis is performed by person rather than by variable, trait, or statement). Respondents are grouped based on the similarities of their Q-sorts, with each group (or factor) representing individuals with similar views, feelings, or experiences about the topic. Each individual with a significant loading ($P < .05$) on one factor is counted on that factor. A factor loading is a correlation between a Q-sort and the factor itself. The standard error of this correlation is estimated by, $SE = 1/\sqrt{N}$ where N is the number of statements [24]. Then, a correlation is statistically significant if it is about 2 to 2.5 times the standard error.

In other contexts, the test-retest reliability of Q-sorting has been found to be 0.80 or higher [26,27]. Content validity is typically assessed by literature review and a team of 3-5 domain experts and is tested in one or more pilot studies. The face validity of the statements is assured by using participants' exact wording of the statements with slight editing only for grammar and readability [28]. Member checking (ie, reviewing factor interpretation with participants) is also useful but could not be included in this study because data collection and analyses were completed after many students had finished their programs and we had not received ethics clearance to track participants.

Positive, negative, and neutral statements about the use of Web conferencing technology were collected during an earlier evaluation of Live Classroom (Wimba, Inc, New York, NY, USA) in the Faculty of Health Sciences. Comments were gathered from responses to an open-ended question in an online evaluation; we also invited Web conferencing users to share their thoughts about Web conferencing. Specifically, we asked them to email at least five statements that reflected how they felt about Web conferencing based on their experience with Live Classroom. They were instructed that "statements should indicate strengths, limitations, barriers or any other things that you think are important for us to know about the technology."Over 100 statements were compiled into one dataset (the concourse). To have a representative Q-sample, we used an inductive process as there was no theoretical hypothesis or framework involved. The statements in the concourse were classified into six domains emerging from the statements themselves, including teaching and learning, access/reach, communication, technical features, technology setup and training, and comfort / ease of use with technology. The statements within each domain were refined, clarified, and significantly reduced by the research team. An iterative consensus process was engaged in which each coauthor independently considered how the statements might be combined, rephrased, or deleted for the sake of clarity and avoidance of redundancy. This process was followed by a group meeting and then more independent consideration, continuing back and forth in this way until consensus had been achieved regarding the most appropriate list of statements. The final set included 42 statements (Multimedia Appendix 1) that represented key ideas from each domain about the use of Web conferencing in education.

Four volunteers agreed to pilot-test the tool, which resulted in minor edits to clarify some statements. Invited participants were then asked to sort the randomly numbered final statements onto a grid, scoring each statement between −4 and +4, where negative scores indicated disagreement, until all blanks on the grid were completed. The grid was constructed such that participants could only assign two statements a score of −4 and two statements a score of +4. Three statements could get a score of −3 and three could score +3, and so on. Detailed instructions, including an example, were provided to participants (Multimedia Appendix 2). The Q-sort was completed by each respondent independently, either in isolation or in a group setting. Participants were also asked to complete a short survey including questions pertaining to demographics and previous experience with Web conferencing (Multimedia Appendix 3).

Analysis

A by-person factor analysis of the Q-sort was conducted to identify groups of participants with similar viewpoints. Finally, for each factor a weighted (synthetic) Q-sort was produced using a weighted averaging method to calculate the score for each statement for that factor [24]. This synthetic Q-sort represents the set of responses to statements that are held by a person who typifies that particular standpoint. To generate the synthetic Q-sort, the statistical programs use only the scores for those participants who loaded on the factor. The scale of this synthetic Q-sort is basically a normalized Z-scale. However, these scores can easily be converted to the original Q-sort format, the two statements with the highest weighted composites being assigned +4, the next three highest being scored +3, and so forth. PQMethod (version 2.11) was used for the analysis of Q-sorts. PQMethod is a frequently used program developed by Schmolck [25] that can be downloaded freely from his website.

So far, only two methods of factor extraction are implemented in this program: principal component method and centroid method. In addition, only two methods of rotation are available in this program: varimax and judgmental (or manual) rotations. Usually, rotation methods are informed by theoretical reasoning rather than simply by statistical criteria. Interested readers are referred to the guidelines accompanying relevant software for practical guidance or to Brown [26] for a theoretical account. The main difference between principal component method and centroid method is that in principal component the variance of loadings is maximized, where in centroid the average of the loadings is maximized. Although no clear statistical or theoretical advantage is provided in Q-methodology literature, there is great sympathy among Q-methodologists for using the centroid method. We used the centroid method for factor extraction. All authors met as a group over a half day to interpret the factors; consensus was quickly reached in assigning a name to each factor and describing the viewpoint since the pattern of statements clearly pointed to unique and distinguishing views.

Results

Participants

A total of 36 people participated in the study. Each participant who completed the Q-sort had previous exposure to the technology, ranging from attendance at a Web conference (set up and managed by someone else such as a faculty member or technical support person) to being highly engaged (setting up, connecting, and actively participating in a Web conference from a remote location). Participants had connected as a group from their classroom or alone from a remote location such as an office or home (Table 1). One participant connected from South America.

Table 1. Description of participants (N = 36)

	Number	Percentage
Participant		
Medical residents in anesthesiology	14	39
Nursing graduate students	11	31
Health sciences faculty	9	25
Health sciences staff	2	6
Gender		
Male	12	33
Female	24	67
Experience with Web conferencing		
Participant	26	72
Guest presenter	2	6
Moderator	1	3
Supported others to run a Web conference	1	3
Multiple roles	6	17
Connection points *		
Classroom	20	59
Office and other location	6	18
Home	5	15
Other	3	9

*There were two 2 responses missing for one question related to connection points.

Participants were asked about their experiences in setting up Web conferences, such as uploading a presentation or creating multiple-choice questions or polls. Of the 36 participants, 53% had never set up a Web conference (they arrived to a room where the setup was done for them); 22% had content set up by others; 14% had uploaded materials for a Web conference themselves; and 11% were unsure about their past experiences. Most participants were not developers of the technology but represented general users. Therefore, our sample included people with a range of experience in Web conferencing, which is typical of most situations when a new technology is introduced.

Major Viewpoints

Three major viewpoints emerged from the Q-sort analysis, each of which presented generally positive opinions of Web conferencing; 34 participants loaded on three factors, which we labeled factor 1, pragmatists; factor 2A, positive communicators; and factor 2B, shy enthusiasts. These factors explained 28% (factor 1) and 11% (factor 2, including 2A and 2B) of the total variance, respectively. Although the total of 39% is less than what is seen in ordinary factor analysis, in Q-methodology the main objective is finding the preferences (or salient viewpoints), not identifying the number of factors that can explain a large percentage of the total variations. Two participants did not load on any of the factors.

The majority of our respondents (n = 26) loaded on factor 1, the pragmatists. Table 2 lists the scores for the distinguishing statements for this factor, which vary from −4 to +4, where negative scores indicate disagreement with the statement. In this group, there was strong agreement with four statements: (1) “Web conferencing provides students with flexibility to participate when off-site”; (2) “Although face-to-face meetings are better than Web conferencing, for those people who can’t be there, Web conferencing is useful”; (3) “There is potential for technical difficulties during Web-conferencing, which can jeopardize its effectiveness”; and (4) “There is potential for Web conferencing to support education.” They strongly disagreed with the statements “I am much less shy communicating from home, than I would be on-site!” and “I would prefer to attend seminars online rather than face-to-face for cost savings.” Therefore, this group of respondents endorsed the value of Web conferencing for its increased flexibility and easy access for distant participants while being realistic about problems with ease of use and potential technical difficulties that could jeopardize the experience. Although pragmatists generally preferred face-to-face meetings, they also felt that “if you can’t be there,” Web conferencing can be a useful technology.

Table 2. Factor 1 scores for distinguishing statements for pragmatists (n = 26)*

Statement	Pragmatists Factor 1	Positive Communicators Factor 2A	Shy Enthusiasts Factor 2B
Web conferencing provides students with flexibility to participate when off-site.	**4**	2	−1
Although face-to-face meetings are better than Web conferencing, for those people who can't be there, Web conferencing is useful.	**3**	0	−3
There is potential for technical difficulties during Web conferencing, which can jeopardize its effectiveness.	**3**	0	−1
There is potential for Web conferencing to support education.	**3**	0	0
I would prefer to attend seminars online rather than face-to-face for cost savings.	**−3**	0	4
I am much less shy communicating from home than I would be on-site!	**−4**	−1	3

*Negative scores denote disagreement with the statement.

Factor 2 was a bipolar factor, which implies that two opposite viewpoints, representing two groups of participants, loaded significantly on the same factor. A bipolar factor is typically broken down into two factors: one containing Q-sorts with positive loadings and the other containing Q-sorts with negative loadings. Therefore, we split factor 2 into factors each describing a common viewpoint (2A and 2B). Four respondents loaded on factor 2A (Table 3); they held a unique viewpoint represented by the theme of positive communicators. This group strongly agreed with three statements: (1) "Web conferencing can facilitate communication in research teams who are in multiple locations"; (2) "I enjoy trying out a new technology"; and (3) "Web conferencing would be useful to support the supervision of students in distributed locations." They strongly disagreed with the statement "The application sharing tool is a bit confusing for participants and presenters." Positive communicators generally enjoyed new technology and felt that Web conferencing could facilitate communication in a variety of contexts, including education and research team meetings. They were not challenged by the application-sharing feature in which a presenter opens a software application (eg, Internet Explorer, Excel) on their computer to provide a live demonstration to remote participants.

Table 3. Factor 2A scores for distinguishing statements for positive communicators (n = 4)*

Statement	Pragmatists Factor 1	Positive Communicators Factor 2A	Shy Enthusiasts Factor 2B
Web conferencing can facilitate communication in research teams who are in multiple locations.	2	**4**	−2
I enjoy trying out a new technology.	0	**3**	1
Web conferencing would be useful to support the supervision of students in distributed locations.	1	**3**	2
The application sharing tool is a bit confusing for participants and presenters.	0	**−3**	1

*Negative scores denote disagreement with the statement.

The last four respondents loaded on factor 2B (Table 4); they held a viewpoint that could best be described as shy enthusiasts. This group of respondents strongly agreed with the following: (1) "I find Web conferencing software extremely easy to use"; (2) "I would prefer to attend seminars online rather than face-to-face for cost savings"; (3) "The ability to use multiple-choice questions and open-ended questions is a very important feature in Web conferencing"; and (4) "I am much less shy communicating from home than I would be on-site!" They disagreed with the statements "Although face-to-face meetings are better than Web conferencing, for those people who can't be there, Web conferencing is useful," and "Nonverbal communication in the classroom is missed by those online; this can cause confusion." Shy enthusiasts clearly preferred Web conferencing to face-to-face seminars and were comfortable with the technology overall. The ability to interact online by responding to multiple-choice or open-ended questions was valued. In addition, they were less shy meeting from a remote location compared to face-to-face and did not feel disadvantaged with the lack of nonverbal communication cues when communicating online. During this study, no participants used the video feature. All four of these participants were anesthesiology residents.

Table 4. Factor 2B scores for distinguishing statements for shy enthusiasts (n = 4)*

Statement	Pragmatists Factor 1	Positive Communicators Factor 2A	Shy Enthusiasts Factor 2B
I find Web conferencing software extremely easy to use.	−2	−1	**4**
I would prefer to attend seminars online rather than face-to-face for cost savings.	−3	0	**4**
The ability to use multiple-choice questions and open-ended questions is a very important feature in Web conferencing.	−2	0	**3**
I am much less shy communicating from home than I would be on-site!	−4	−1	**3**
Although face-to-face meetings are better than Web conferencing, for those people who can’t be there, Web conferencing is useful.	3	0	**−3**
Nonverbal communication in the classroom is missed by those online; this can cause confusion.	0	−2	**−4**

*Negative scores denote disagreement with the statement.

Extreme Scores and Consensus Statements

Table 5 illustrates statements that yielded extreme scores that were not distinguishing statements but that can be of particular interest because they represent the most prominent likes and dislikes of the participants loaded on one factor [26]. For example, the statement “Web conferencing can enhance distance education through increased access to seminars, rounds, etc.” was given a high score by both pragmatists and positive communicators.

Table 5. Statements with extreme scores for each factor*

Statement	Pragmatists Factor 1	Positive Communicators Factor 2A	Shy Enthusiasts Factor 2B
Pragmatists , factor 1			
Web conferencing can enhance distance education through increased access to seminars, rounds, etc.	**4**	4	0
I feel very involved when I am in a Web conference.	**−3**	2	2
Positive communicators, factor 2A			
Web conferencing can enhance distance education through increased access to seminars, rounds, etc.	4	**4**	0
The audio feature is a very important function of Web conferencing.	2	**3**	−1
I experience extensive anxiety about my ability to set up the teleconference and more anxiety about my ability to “troubleshoot” in the middle of a session.	−2	**−3**	1
Lack of video is an issue.	−1	**−3**	−2
Shy enthusiasts, factor 2B			
Overall, the quality of Web conferencing technology is very good.	−1	2	**3**

*Negative scores denote disagreement with the statement.

Pragmatists did not feel as highly involved when taking part in a Web conference compared to positive communicators and shy enthusiasts. Like positive communicators, however, they felt strongly that Web conferencing could enhance distance education by providing increased access to various educational offerings such as seminars and rounds. Positive communicators expressed less anxiety about setting up Web technology, valued the audio feature more, but missed the video component less than the other groups. Finally, shy enthusiasts felt more strongly that the overall quality of Web conferencing was very good. All groups generally agreed that the video feature was unimportant; however, it should be noted that the video feature was not used during the trial due to its poor quality.

Although all three groups had different viewpoints on a number of aspects of Web conferencing, there was consensus on several statements (Table 6). All participants felt strongly that students would enjoy Web conferencing and agreed that more training would be useful. They also disagreed with the idea that Web conferencing would hamper their interactivity online and that the technology ran slowly. Participants from all three groups felt that Web conferencing was superior to audio conferencing alone.

Table 6. Consensus statements*

Statement	Pragmatists Factor 1	Positive Communicators Factor 2A	Shy Enthusiasts Factor 2B
The PowerPoint slide presentation function is very important for Web conferencing.	2	1	1
Web conferencing is a more interesting way to connect people at a distance than audio conferencing.	1	2	1
More Web conferencing training sessions are necessary.	1	1	2
Web conferencing technology is not always compatible with the computer resources I have at home.	0	−1	0
The ability to record and archive seminars is extremely convenient for people who are unable to attend scheduled presentations.	1	1	0
I think Web conferencing would be useful for workshops/training for staff at their workstations.	−1	0	0
Web conferencing runs slowly.	−2	−2	−3
I did not feel that Web conferencing promoted interactivity with those people located at remote sites.	−3	−4	−4
Students accustomed to face-to-face learning will not enjoy Web conferencing experiences.	−4	−4	−3

*Negative scores denote disagreement with the statement.

Of females who loaded on factors, 86% (19/22) were pragmatists compared to 58% (7/12) of all males. The two administrative staff who participated in the study worked with Web conferencing the most. They were involved in setup and providing service/support. Both fell into the pragmatist group. Pragmatists also tended to include participants with varied Web conferencing experience, such as being a guest presenter and/or a moderator, providing support to others, as well as being a general participant.

Discussion

Web Conferencing in Education

With the increasing application of Web conferencing technologies in education, the results from our study provide an important contribution to understanding general users' viewpoints on the role of Web conferencing as a synchronous communication system to support health sciences education. Based on our participants' positive viewpoints on Web conferencing in health sciences education, a decision was made to continue to fund Web conferencing in the faculty. Their positive views were similar to other reports in the literature [11-13]. The most cautious/circumspect group was the pragmatists, who made up 72% of the total participants. They tended to have more varied hands-on experience with Web conferencing and thus were more likely to have experienced problems that can occur, thereby influencing their "pragmatic" views. As was pointed out in papers by Ostrow and DiMaria-Ghalili [13] and Shield et al [11], there are technical issues with Web conferencing that educators and technicians need to overcome, such as bandwidth limitations, firewall and security filters that block access, audio quality and screen sizing issues, and problems installing a client needed to run the Web conferencing software. We also experienced these issues at our site. Despite the problems, positive communicators envisioned the use of this technology for broader applications, including research and administration.

Our participants felt that more training would be useful. As others have identified, it is important to provide greater faculty orientation to ensure that minimal technical support is needed [12]. This has implications for the implementation of Web conferencing within faculty of health sciences programs, which often have many instructors who make only occasional teaching contributions. The steep learning curve for moderators and participants necessitates more technical support for occasional moderators. This is a useful caveat with regard to rolling out various features of Web conferencing since we observed that moderators generally used few features in their initial Web conferences but were more likely to introduce additional features, such as polling, in subsequent conferences.

It is somewhat surprising that learners were generally positive about Web conferencing given the lack of faculty training in instructional design methodologies and best practices for synchronous e-learning. While some moderators used the occasional interactive component such as polling, most moderators provided simple audio commentary of bulleted text slides. It is possible that improved use of Web conferencing best practices—such as using meaningful visuals, multimedia, and interactions like polling, application sharing, and chats—may have resulted in even more enthusiasm for the technology [29]. As with most pedagogical interventions, the quality of the instructional methods is more important than the medium or the technology itself [30].

The shy enthusiasts group may have comprised participants who experience social anxiety. It should be noted that although shy enthusiasts found the technology very easy to use, they were all attendees at a Web conference and did not have to set up or configure computers themselves. They participated as a group in a classroom with a faculty member presenting remotely.

Although the four participants in the shy enthusiast group happened to be anesthesia residents, anesthesia residents also fell into the other two groups. Shyness has not been found to be related to use of chat rooms or email [31], but it has been found to be related to higher Internet use [32].

Our findings show that while Web conferencing was preferred over teleconferencing alone, the video feature was not highly valued by participants. This finding is supported in a study of two groups of dental students in Michigan who used podcasting to listen to lectures via audio alone or audio synchronized with PowerPoint and video [33]. The students reported a high preference for audio alone; they used the archives of lectures to review material after class and before exams and also as a safety net when they could not keep up with note-taking in information-dense classes. Although podcasting is an asynchronous communication system, it is not clear if the results are transferable to a synchronous context. Others have indicated that they have experienced problems with video caused by low bandwidth [12]. As the quality and ease of use of video delivery over the Web to personal computers improves, it is expected that its use will likely increase. Further studies to examine best practices for the application of video to support synchronous communication are needed. In the meantime, there appears to be good acceptance of audio and text alone.

Q-Methodology in Educational Research

Q-methodology proved to be a useful and unique approach to investigating this educational research topic as the study benefited from both qualitative and quantitative perspectives. The validity of our interpretation of the results relies on the use of factor analysis in extracting the distinguishing statements and on the use of domain experts in interpretation. The accuracy of the interpretation could be further verified by asking the relevant (significantly factor-loaded) participants to comment on their views about the results of the study, although we could not conduct follow-up interviews. Despite this limitation, we had adequate numbers in our sample for the use of Q-methodology, as seen by the emergence of three clear and distinct factors. Perhaps our findings would have differed if the contexts for the use of Web conferencing were more varied. There were other applications of Web conferencing used during our trial, such as for support of multi-site research and pan-Canadian and international meetings. This evaluation did not focus on such applications, although some statements were included that referred to broader technology applications. Our study focused on the opinions of participants who were general users of the technology to support educational needs of health sciences students as opposed to experts. As ease of use and quality of Web conferencing increase, we might expect to find even more positive responses from participants in academic settings.

Conclusion

This study contributes new knowledge about general users' (faculty, student, and staff) viewpoints on Web conferencing technology as a support for health sciences education (see Multimedia Appendix 4 for a PowerPoint presentation of the study). All participants felt positively about the use of Web conferencing to support education, but for different reasons. Furthermore, there were no strongly negative views, thereby providing support for continued growth of such technologies in academia. Participants viewed Web conferencing as an enabler, especially where face-to-face meetings were not possible. Audio features of the software were highly valued, while video features were not particularly missed. Our findings indicate that adequate technical support and training must be provided for successful ongoing implementation of Web conferencing. More research is needed to determine best practices for the use of Web conferencing in various educational contexts. Our promising results provide an impetus for the continued application of Web conferencing technology to facilitate the delivery of health sciences education programs. Q-methodology was a useful research approach and is suggested in future exploration of the use of Web technologies to facilitate communication in education, research, and administration activities.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Final statements for the Q-sort [PDF file (Adobe PDF), 108 KB - jmir_v9i5e39_app1.pdf]

Multimedia Appendix 2

Instructions for participants completing the Q-sort [PDF file (Adobe PDF), 108 KB - jmir_v9i5e39_app2.pdf]

Multimedia Appendix 3

Demographic survey [PDF file (Adobe PDF), 76 KB - jmir_v9i5e39_app3.pdf]

Multimedia Appendix 4

PowerPoint presentation of study results [PPT file (MS Powerpoint), 2.2 MB - jmir_v9i5e39_app4.ppt]

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Original Paper

No Increase in Response Rate by Adding a Web Response Option to a Postal Population Survey: A Randomized Trial

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Abstract

Background: There is substantial interest in use of the Internet for surveys, but there have been few health-oriented, large, randomized trials of general population surveys on the Internet. It is unclear whether providing the option to respond via Internet increases the response rate, and to what degree the results will differ.

Objective: The aim of the study was to evaluate changes in response rate and outcomes in a postal respiratory health survey by adding an optional Web response alternative.

Methods: This was a randomized trial of a random sample of 4213 permanent residents of Norway, aged 20-40 years. Participants were randomized into a traditional survey arm, where they were asked to return the survey by mail, and an arm where they were also offered the option to respond via a Web form.

Results: A total of 1928/4213 subjects responded, a response rate of 45.8% across both arms. The total response rate was 44.8% (944/2105) in the postal plus optional Internet response arm and 46.7% (984/2108) in the usual postal survey arm, with no statistically significant difference between the randomized groups (P = .24). In the optional Internet arm, 8.3% (175/2105) of the sample responded using the Internet and 36.5% (769/2105) responded by post. Thus, Internet response was chosen by 18.5% (175/944) of those who replied in the optional Internet arm. In the multivariate analysis, Internet response was associated with being male, frequency and type of Internet access (home users more likely to respond by Internet than work users), and smoking habit, with current smokers being more likely to be Internet responders. 57% preferred postal response (1102/1928), 38% preferred Internet response (733/1928), and 3% preferred telephone interview (54/1928), with no difference between randomization arms (P = .56). But among those who indicated that they preferred the Internet response and who were randomized to the optional Internet arm, only 47% actually chose the Internet response. Asthma prevalence was higher among participants choosing the Internet response mode (16.7% vs 12.4%).

Conclusions: We failed to increase survey response rates by adding an optional Internet response. Asthma diagnosis was higher in the Internet response group, suggesting nonresponse bias. Method comparison studies should be carried out before Internet studies are accepted in new populations or new subject matters.

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KEYWORDS

Internet; randomized control trial; questionnaire; epidemiology; response rate; bias

Introduction

The population survey remains a cornerstone of public health research and epidemiological inference. There is a substantial interest in using the Internet for surveys because of speed, low cost of data collection, and potentially large sample sizes and also because of falling response rates with conventional surveys [1-3]. On the one hand, there is substantial literature on Internet-focused surveys, based on Internet-only populations [4]. An ongoing concern is the possibility of generalizing from these populations accessible through the Internet to general populations. There is both theoretical and empirical evidence of self-selection bias [5,6]. On the other hand, a somewhat separate branch in the rich literature on survey methods has studied ways of using the Internet in a more traditional population survey process [7]. A number of studies have been done in various special populations: students [8,9], businesses, occupational and election surveys, and email lists [10-13]. There is also an academic online database focusing on Internet survey methodology.

However, there are few directly comparative studies that can directly answer the question of what the role of the Internet in a general population survey could be. Such studies would use a geographically defined general population and rigorous randomization to isolate the Internet factor only.

The Choice of Survey Method

The choice of basic survey method is not always clear cut and varies regionally and by the traditions in the subject field. Large surveys still use in-person interviews (eg, National Health and Nutrition Examination Survey), postal questionnaires (eg, American Community Survey, the successor to the US Census Bureau decennial census), or an eclectic mix of all modes (eg, World Health Organization's World Health Survey [14]). This growing role of mixed-mode surveys adds additional complexity, as recently reviewed by de Leeuw [15]. For the next few years, the Internet is going to be an optional add-on to more conventional survey methods in general population surveys.

Scarcity of Randomized Trials

Through various literature searches and contact with experienced survey technologists through survey mailing lists, we were able to find only four prior studies that evaluated use of the Internet for surveying a geographically defined general population in a randomized fashion [16-19].

Norway has an excellent sampling frame available to researchers through the National Central Population Registry. All permanent residents are required by law to register. Internet access is common in Norway, with 42% of Norwegians accessing the Internet daily in 2003 [20]. Thus, Norway is a good setting in which to test whether response rates are increased by adding an Internet response option to a postal survey.

In this study, we performed a randomized trial in adult Norwegians, comparing a regular postal survey with a postal survey that had an optional Internet-based response. Our hypothesis was that the addition of the Internet response option to a postal survey would increase response rate with little bias from the mix of survey modes.

Methods

Design

We performed a parallel group randomized trial of the Norwegian general population. In April 2004, we randomly selected 4213 persons aged 20-40 years from the Norwegian Central Population Registry, covering all of Norway. Age, gender, and county of residence were taken from the registry. All other variables were recorded from the questionnaire. Half of the participants were randomized to the postal plus optional Internet response intervention (n = 2105), the rest to the standard postal survey (n = 2108). Simple randomization was performed without stratification or blocking. Participants were blinded to the randomized nature of the study. The study was powered to have 90% power to detect a 5% difference in response rates at an alpha level of .05 (50% vs 55%). The survey was performed from April to August 2004.

Postal Component

All participants were mailed a one-page introductory letter explaining that the purpose of the study was to establish the occurrence of and risk factors for asthma and allergies in Norway. They were also mailed a one-page questionnaire containing 40 questions on respiratory symptoms and diagnoses that has been used extensively in previous work [21,22], as well as questions on morbidity, known and suspected risk factors, and use of modern communication methods. A pre-paid response envelope addressed to the sponsoring institution was enclosed. The intervention group additionally received a one-page sheet describing the optional use of the Internet response, along with a 7-digit user identification and 4-digit password. One reminder containing another copy of the questionnaire and pre-paid response envelope was sent by mail to nonresponders after 6 weeks.

The postal survey cost €2 (US $1.75) per person in printing and mailing costs, excluding workload. The additional cost of printing and mailing the Internet response explanation sheet and setting up the Web server was approximately €0.35 (US $0.26) per person. Setting up the server took a few days of work for the first author.

Web Server

The Internet Web server was set up by the first author. The server was a standard commercial Windows server with Active Server Pages (.ASP). There were no client-side scripts or cookies. The opening page was brief (105 words) and contained a prominent user identity and password box. There were 11 text-only questionnaire pages, containing 1-14 questions viewable on all platforms with an 800 × 600 pixel screen without scrolling. Sign-in was performed by entering a numeric user ID and numeric password printed on the questionnaire (Multimedia Appendix 1). A pilot study using friends and coworkers (n = 17) showed that the Web questionnaire was easily completed and took less than 15 minutes. Identity was ascertained through log-in. There were no potentially identifying questions or data such as age, gender, or municipality of residence, and Internet protocol (IP) numbers were not logged.

Statistical Methods

The primary analysis was by intention-to-treat, comparing response rates overall and in various subgroups. Secondary analyses included predictors of choosing the Internet response in the postal plus optional Internet response arm, as well as changes in the main outcomes of the survey (self-reported demographics and prevalence of outcomes) with survey mode. Change in prevalence of symptoms with number of mailings was taken as an indicator of nonresponse bias. Participant preference for response mode was assessed both by asking about preferred response mode (postal, Internet, or telephone) and by contrasting with their actual choice of survey response mode. The question was “If you could choose how to respond to this or a similar survey, what would you choose?” The options were “Receive a call from an interviewer” or “Receive a questionnaire by mail and…,” then either “Send in the completed form by mail” or “Answer on the Internet.”

Age was categorized as 20-24, 25-30, 30-34, and 35-40 years. All other variables were categorical. County of residence was classified into rural or small urban, medium urban, and large urban based on conventional Norwegian cutoff points according to county population size (< 8000, 8000-50000, > 50000). Statistical comparisons used the chi-square test for univariate analysis, whereas multivariate analyses used multiple binomial logistic regression.

The study was recommended by the Regional Committee for Medical Research Ethics in Norway and had the appropriate permission from the Norwegian Data Protection Authority through a simplified procedure with the Norwegian Social Science Data Services.

Results

Response Rates

The randomized groups were well matched for gender, age, and municipality size (Table 1). A CONSORT-style [23] flowchart is available in Multimedia Appendix 2.

Table 1. Comparison of randomized arms by age, gender, and population density of municipality of residence

	Postal (n = 2108)	Optional Internet (n = 2105)
% men	51.8	49.9
Age (years), mean (SD)	30.7 (6.07)	30.7 (6.04)
Residential density (%)		
Rural or small urban	43.0	43.0
Medium urban	21.6	23.1
Larger urban	35.4	33.9

A total of 45.8% (1928/4213) individuals responded. The total response rate was 44.8% (944/2105) in the postal plus optional Internet response arm and 46.7% (984/2108) in the usual postal survey arm, with no statistically significant difference between the randomized groups (P = .24; Table 2). In the optional Internet arm, 8.3% (175/2105) of the sample responded using the Internet and 36.5% (769/2105) responded by post. There was a significantly lower response rate in the optional Internet arm (36.7%) compared with the usual postal arm (44.2%) in the 20-24 age range (P = .02).

Response rates were 31.4% (661/2105) and 31.6% (667/2108) after the first letter, and an additional 13.4% (283 additional responses) and 15.0% (317 additional responses) after the reminder letter in the postal plus optional Internet and usual postal arms, respectively (P = .28). Response rates were more than 10% higher in women in both treatment arms (P < .001). There was no age trend in response in the usual postal arm (P = .23), but a significant trend in the postal plus optional Internet arm (P < .001), driven by the lower response rate in the 20-24 age group. There was no trend by residential status. The same results were found when analyzing trends in response rates according to initial and reminder letter response (data not shown).

Table 2. Effect of intervention on response rate

		Trial Arms					Within Optional Internet Arm			
		Postal (n = 2108)		Optional Internet (n = 2105)		*P*	Postal Response (n = 769)		Internet Response (n = 175)	
		%	No.	%	No.		%	No.	%	No.
Gender										
	Male	41.9	457/1091	38.2	402/1051	.09	29.0	305/1051	9	97/1051
	Female	51.8	527/1017	51.4	542/1054	.86	44.0	464/1054	7	78/1054
Age (years)										
	20-24	44.2	200/452	36.7	159/433	.02	29.6	128/433	7	31/433
	25-30	45.3	196/433	44.4	206/464	.84	34.1	158/464	10	48/464
	30-34	45.8	242/528	50.6	252/498	.13	42.4	211/498	8	41/498
	35-40	49.8	346/695	46.1	327/710	.17	38.3	272/710	7	55/710
Residential density										
	Rural or small urban	44.4	402/906	44.2	400/906	.96	37.2	337/906	7	63/906
	Medium urban	47.6	217/456	44.0	214/486	.30	35.6	173/486	8	41/486
	Larger urban	48.9	365/746	46.3	330/713	.32	36.3	259/713	10	71/713
Total		46.7	984/2108	44.8	944/2105	.24	36.5	769/2105	8.3	175/2105

Expressed Preference and Chosen Response Mode

Internet access and type of Internet access would seem important explanatory factors in this study. Among all respondents from both arms, more than 90% had access to the Internet: 59% both at work and at home (1144/1928), 15% at home only (291/1928), and 17% at work only (321/1928); however, 7% had no Internet access (125/1928).

An evaluation of the predictors of choosing the Internet response option among the respondents in the optional Internet arm is given in Table 3. In the univariate analysis, Internet response was associated with being male, frequency and type of Internet access, and planned education. In the multivariate analysis, Internet response was associated with being male, frequency and type of Internet access, and smoking habit. The strongest predictor of Internet response was Internet use or access type, followed by gender. Interestingly, current smokers were more likely to be Internet responders.

We evaluated which response mode respondents actually chose as well as their expressed opinion on their preferred response mode. Respondents were asked their preferred method of survey response—postal, telephone interview, or Internet; 57% preferred postal response (1102/1928), 38% preferred Internet response (733/1928), and 3% preferred telephone interview (54/1928), with no difference between randomization arms ($P = .56$). But among those who indicated that they preferred the Internet response and who were randomized to the optional Internet arm, only 47% actually chose the Internet response. While 97% (170/175) of actual Internet respondents expressed a preference for Internet response, 26% (193/752 responders to the question) of the postal respondents in the Internet randomization arm also expressed a preference for Internet response—a “false preference.” In multivariate analysis, this preference discrepancy was not associated with age ($P = .73$) but was strongly associated with male gender ($P < .001$), never smoking ($P = .02$), larger urban residence ($P = .07$), and higher educational achievement ($P < .001$).

We evaluated predictors for choosing the Internet response among the 363 persons in the Internet arm who had an expressed Internet response preference in a logistic regression using gender, smoking, age, planned education, residential density, type of Internet access, and intensity of Internet use. The only significant variable was type of Internet access ($P = .02$): in this group, 50% of those with Internet access at home chose the Internet response option, compared to 23% of those with Internet at home and 20% with no Internet access.

Table 3. Percent choosing the Internet response among respondents in the postal plus optional Internet arm (n = 944)

	%	Univariate *P* Value	Multivariate OR	95% CI	Multivariate *P* Value
Total	18.5 (175/944)				
Male	24.1	< .001	1 (ref)		.05
Female	14.4		0.69	0.47-1.00	
Age (years)					
20-24	19.5	.20	1 (ref)		.14
25-29	23.3		0.98	0.54-1.77	
30-34	16.3		0.66	0.36-1.22	
35-40	16.8		0.58	0.31-1.06	
Residential status					
Rural or small urban	15.8	.13	1 (ref)		.07
Medium urban	19.2		1.62	0.99-2.64	
Larger urban	21.5		1.55	1.01-2.39	
Internet use					
Daily	27.3	< .001	1 (ref)		< .001
Weekly	10.2		0.31	0.18-0.51	
Seldom	3.4		0.10	0.03-0.33	
No access	1.6		0.05	0.01-0.37	
Internet access[*]					
At home	23.2	< .001	1 (ref)		< .001
At work	5.0		0.13	0.06-0.30	
None	1.5		0.06	0.1-0.47	
Educational level now[†]					
Primary school	18.6	.31	1 (ref)		.40
High school/vocational	17.9		0.92	0.42-2.03	
College	16.7		0.79	0.34-1.79	
University	24.1		1.26	0.53-2.98	
Planned education					
Primary/high school	15.2	.006	1 (ref)		.15
College	18.4		0.99	0.62-1.58	
University	25.7		1.50	0.92-2.45	
Relationship status					
Married	17.3	.83	1 (ref)		.70
Cohabiting	20.1		1.01	0.62-1.66	
Single	18.5		0.83	0.48-1.41	
Other	20.0		1.25	0.59-2.62	
Smoking habit					
Never	17.6	.12	1 (ref)		.005
Former	15.8		0.89	0.57-1.39	
Current	23.4		2.06	1.26-3.37	

[*]Multivariate odds ratio estimated from a separate model without Internet use intensity included, due to colinearity.

[†]Multivariate odds ratio estimated from a separate model without planned education included, due to colinearity.

Main Survey Results by Randomization and Survey Mode

Table 4 shows the main survey results by randomization and chosen response mode. Adding an Internet response mode did not change the overall results of the survey, both for demographic variables and health outcome variables, except for asthma diagnosis. Asthma diagnosis was reported more often in the group randomized to the optional Internet response arm, in both the postal and Internet responders.

Internet responders as a group were somewhat different from postal responders. They were much more likely to be male and somewhat more likely to be smokers and have higher educational aspirations (but not achievements). They were also more likely to report phlegm and morning cough.

Table 4. Main survey results (demographics, prevalence of symptoms, and diagnoses), according to randomization and chosen response mode in the optional Internet response arm

	Randomized Arm			Optional Internet Arm		
	Optional Internet (n = 944)	Postal (n = 984)	*P* Value	Internet Response (n = 175)	Postal Response (n = 769)	*P* Value
Demographic variables						
Age (years), mean (SD)	31.2 (5.9)	30.9 (6.1)	.26	30.7	31.4	.17
Gender, % men	43	46		55	40	< .001
Smoking habit, former	28	28	.99	24	29	.11
Smoking habit, current	21	21		26	19	
Educational level now, primary	6	6	.08	7	6	.30
Educational level now,high school	47	51		46	47	
Educational level now, college	31	26		28	32	
Educational level now, university	15	17		20.1	14	
Educational level planned, primary/high school	42	44	.56	34	44	.006
Educational level planned, college	33	31		33	33	
Educational level planned, university	24	25		33	22	
Symptoms and diagnoses						
Morning cough, % yes	18	20	.44	24	17	.03
Day cough, % yes	13	14	.74	15	13	.30
Phlegm, % yes	21	23	.39	30	20	.003
Chronic cough, % yes	12	11	.62	13	12	.63
Dyspnea grade 1, % yes	18	19	.81	21	17	.23
Dyspnea grade 2, % yes	14	11	.09	18	13	.07
Dyspnea grade 3, % yes	3	2	.06	3	3	.71
Dyspnea grade 4, % yes	2	1	.50	3	1	.05
Attacks of breathlessness, % yes	15	13	.19	17	15	.43
Wheezing ever, % yes	25	23	.30	27	25	.44
Prolonged episodes of cough and phlegm, % yes, once	18	18	.69	21	18	.29
Prolonged episodes of cough and phlegm, % yes, multiple times	16	17		18	15	
Hay fever, % yes	27	27	.89	31	27	.29
Hay fever, % missing	22	21		18	23	
Eczema, % yes	19	20	.58	15	20	.14
Eczema, % missing	20	22		24	19	
Asthma diagnosis, % yes	13	9	.03	17	12	.18
Asthma diagnosis, % missing	1	1		0	1	

Phlegm and morning cough were reported more often among those who chose the Internet response. We also performed an adjusted analysis of the association between symptoms and diagnoses and chosen response mode in the Internet arm, adjusting for age,gender, and smoking (not shown). The association remained for phlegm after this adjustment (P = .02), but not for morning cough.

For most outcomes, there was no difference in the prevalence of outcomes between initial and reminder letters in either treatment group (data not shown). However, there was a trend in the usual postal group for chronic cough and hay fever: chronic cough was 10% (64/657) versus 15% (46/307) for initial and reminder letter responders, respectively (P = .02); hay fever was 29.0% (19/659) versus 23% (70/309; P = .01).

Discussion

We added an easily implemented, low-cost, optional Internet response to a general population postal health survey with randomization, a large sample size, and widespread geographic coverage. We took advantage of a cooperating national population with a well-defined sampling frame and widespread Internet access. The main findings were that response rates were unchanged and there were demographic predictors of Internet response. There was also some indication of bias according to traditional measures, such as differences in asthma prevalence between survey modes and between early and late responders, but for a small number of questions.

The results of this trial regarding response rates are probably generalizable to other countries since access to the Internet in Norway is comparable to many European and North American countries [24] and population surveys are widespread. Cost were negligible and workload light.

We identified three previous optional Internet response studies: two saw a 5% to 15% decrease in response rate [16,18], and one saw a 2.5% increase in response rate [17]. Another study randomized subjects to Web-only response, which gave a poor 15% response rate [19].

As with most previous studies, this was not a study of a true "Internet population survey." The rationale was that an Internet-only response mode was unlikely to achieve adequate response rates. Our results are similar to these previous studies: no meaningful increase in the response rate by optional Internet response, regardless of subject matter. It is unlikely than an Internet-only response option would generate acceptable response rates within the next few years to be feasible for surveys.

Why was the total response rate not increased? One possibility is technical problems with the website. However, the website was pilot tested and had a very simple design, so this is unlikely. Our Internet response option was meant to increase response rates by reducing the response effort compared to pencil-and-paper response. The high expressed preference for Internet response, but lower use, is puzzling and could shed light on this issue. This preference discrepancy was strongly associated with male gender, higher education, not smoking, and urban residence. This could suggest that Internet response is likely to increase in the future, in that current Internet responders are the "early adopters." On a more negative note, it could also be an appeasement bias, with responders like to identify with the more recent and novel survey technology. Whatever the case may be, it is likely that participant response effort was not the limiting factor in determining response rates. In particular, we note the reduced response rate in the youngest age group. This was not associated with a similar expressed response mode preference among the youngest responders. It may be that it is easier to put the questionnaire aside when a Web option is included.

It is possible that with increasing adoption of the Internet, an Internet survey will be able to increase response rates, but even in the current population with high Internet use it did not. This remains a hope more than a fact. Tried and tested predictors of survey success, such as topic saliency, remain more important than survey technology, even though the Web option was easy and low cost.

It should also be said that a high response rate is not the end-all or be-all of survey methods. The traditional comparison of late versus early responders did suggest nonresponse bias, but only in the postal group. This traditional indicator was not present in the Internet survey, which is somewhat reassuring. The optional Internet step could even introduce more nonresponse bias if the additional responders were quite different from the target population. On the whole, the only survey result that was affected in the randomized comparison was asthma diagnosis. This was due to a tendency for both postal and Internet responders in the optional Internet arm to respond positively compared to the usual postal arm. Even though it was the only affected outcome, it is still worrying. The asthma diagnosis is a central outcome for the purposes of this survey, and 4 percentage points change in estimated prevalence is substantial. This could be due to failure of randomization, but this is unlikely given the large sample size and good comparability on baseline demographics. It is also unlikely to be a survey mode effect since it was also present in the postal response. One explanation, which we think is likely, is that the optional Internet arm recruited a somewhat different mix of responders. Though response rates were identical, we think that some healthy subjects were put off by the Internet response option, while some persons with asthma, who otherwise would not respond, were particularly attracted to the Internet option.

This study cannot disentangle survey mode effects from nonresponse bias. But looking at who chose the Internet response and how they differ from postal responders could still be instructive. Internet response was associated with some background variables: Internet access, being male, smoking, and educational aspirations. This partly explains the association between two of the symptoms and Internet response. After adjustment for age, gender, and smoking, this association persisted for phlegm. This might be due to residual confounding by smoking intensity or other unmeasured variables. Yet this underscores the potential for unwanted and unexpected survey mode effects and that Internet response options should not be added to a survey naively.

In conclusion, there was no gain in total response rate by adding an Internet response option to a traditional postal questionnaire survey. Adding an Internet-based response option is feasible and low cost. Asthma diagnosis was higher in the Internet arm, suggesting nonresponse bias. Method comparison studies should be carried out before Internet studies are accepted in new populations or new subject matters.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

Complete website files (containing Active Server Pages code and a Microsoft Access database) [ZIP file (WinZIP ZIP), 128 KB - jmir_v9i5e40_app1.zip]

Multimedia Appendix 2

CONSORT-style flowchart and checklist [PDF file (Adobe PDF), 92 KB - jmir_v9i5e40_app2.pdf]

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