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Contents

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Original Paper

Electronic Health Lifestyle Coaching Among Diabetes Patients in a Real-Life Municipality Setting: Observational Study

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Abstract

Background: Internet and mobile interventions aiming to promote healthy lifestyle have attracted much attention because of their scalability and accessibility, low costs, privacy and user control, potential for use in real-life settings, as well as opportunities for real-time modifications and interactive advices. A real-life electronic health (eHealth) lifestyle coaching intervention was implemented in 8 Danish municipalities between summer 2016 and summer 2018.

Objective: The aim of this study was to assess the effects associated with the eHealth intervention among diabetes patients in a real-life municipal setting. The eHealth intervention is based on an initial meeting, establishing a strong empathic relationship, followed by digital lifestyle coaching and collaboration supported by a Web-based community among patients.

Methods: We conducted an observational study examining the effect of an eHealth intervention on self-reported weight change among 103 obese diabetes patients in a real-life municipal setting. The patients in the study participated in the eHealth intervention between 3 and 12 months. A weight change was observed at 6, 9, and 12 months. We used regression methods to estimate the impacts of the intervention on weight change.

Results: We found that the eHealth intervention significantly reduced weight among diabetes patients, on average 4.3% of the initial body mass, which corresponds to 4.8 kg over a mean period of 7.3 months. Patients who were in intervention for more than 9 months achieved a weight reduction of 6.3% or 6.8 kg.

Conclusions: This study brings forward evidence of a positive effect of a real-life eHealth lifestyle intervention on diabetes patients' lifestyle in a municipal setting. Future research is needed to show if the effect is sustainable from a long-term perspective.

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Introduction

Background

A majority of premature deaths from noncommunicable diseases are preventable by facilitating healthier lifestyles [1,2]. Recent systematic reviews conclude that Web-based and mobile digital electronic health (eHealth) solutions can improve lifestyle behaviors [3-8]; however, they also stress that there is a lack of "...available weight loss interventions suitable to the real-world PC setting, with most research and guideline formulation conducted inside academic silos..." [5] as well as there is a "...need for long-term interventions to evaluate sustainability" [4]. The authors have previously found that eHealth lifestyle coaching providing various behavior change techniques (BCTs) such as tailored information, self-monitoring, lifestyle coaching, in-person feedback, reminders, and person-to-person support based on a strong personal relationship led to a significant

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weight loss of 7.0 kg during a 20-month period [9]. A refinement of this eHealth intervention (LIVA) [10] was implemented in 8 Danish municipalities between summer 2016 and summer 2018 on the basis of a number of qualitative studies [11,12].

Municipalities invest in preventive programs with the ambition of reducing health care professional (HCP) input and time per patient while still enabling tailored and effective care [2,4,13-15]. eHealth lifestyle coaching is markedly more efficient than traditional in-person meetings [16].

In this study, we applied an observational design to investigate the first outcome data on self-reported weight change among diabetes patients participating in an eHealth intervention with municipality HCPs for at least 3 months. We combine these results with literature findings regarding the impact of weight change on diabetes patients' costs in a municipality perspective to estimate the potential savings related to societal costs of diabetes.

The aim of this study was to evaluate data regarding self-reported weight change of eHealth lifestyle coaching among diabetes patients and assess impacts associated with offering the program as tertiary prevention among diabetes patients in Danish municipalities.

Research Design

This is an observational study examining the effect of an eHealth lifestyle intervention on self-reported weight change among diabetes patients in a real-life municipality setting.

Setting and Study Population

The eHealth intervention was implemented in an ongoing process in 8 Danish municipalities between summer 2016 and summer 2018. Each municipality offered the eHealth intervention within their own organizational framework with local HCPs such as dieticians, nurses, physiotherapists, and occupational therapists, with wide decision discretion resulting in a heterogeneous program setting.

The study population consisted of 103 diabetes patients obese at baseline, with body mass index (BMI) ≥30, who (1) had used the eHealth platform at any time point between June 7, 2016,

and May 2, 2018, (2) had registered to use the platform because of their diabetes, (3) had at least 90 days and maximum 365 days between their first and the last weight measurement registration, and (4) had no registrations of unrealistic rapid weight change (>0.5 kg/day). All data on patients were collected from the intervention database based on patients' own and their HCPs' registrations.

Methods

Intervention

An eHealth lifestyle coaching intervention has been developed by applying the experiences from previously developed Web-based eHealth solutions used by approximately 140,000 individuals for more than 15 years on which extensive research has been conducted [6,11,16,17].

The key concepts in the eHealth intervention are listed in Textbox 1, and an overview is given in Figure 1.

The intervention provides various BCT's evidenced to be effective for changing lifestyle such as tailored information, self-monitoring, lifestyle coaching, in-person feedback, reminders, and peer-to-peer support [18]. By establishing a personal relationship initially in a face-to-face meeting, which is then continued digitally through the eHealth intervention, the intervention enables tailored care and sustained patient engagement over time with a minimal of HCP input in the process of successfully changing lifestyle and sustaining this change [6,9,16].

Participants in the intervention were introduced to the eHealth intervention by a municipal HCP during a first face-to-face meeting of approximately 45 min to 60 min. Together, the participant and the municipal HCP established a relationship and agreed on goals for diet, physical exercise, sleep, and other life areas if relevant. Goal setting is based on the specific, measurable, attainable, relevant, and timely (SMART) model according to a predefined guideline structure, described in Table 1. All advices are based on recommendations from the Danish National Board of Health.

Textbox 1. Key concepts of the electronic health intervention.

1. Establishment of an empathic relationship with a health care professional (HCP) in an initial face-to-face meeting.

2. Integration of main stakeholders (HCPs in the municipalities and the patients' personal profile through smartphone or Web-based), allowing for HCPs to look over the shoulder of the patient.

3. Intuitive design enables ease of use for both the user (<1 min for registration a day) and HCPs (5-10 min per consultation) developed through ongoing extensive and systematic user involvement.

4. Different modes of communication channels allow for active communication at all levels of prerequisites among users, creating peer-to-peer support.

5. The backend control panel, including a content library and communication templates, enables optimizing of tailored quality advices asynchronously and via short message service text messaging and video.

Figure 1. Overview of the eHealth intervention.
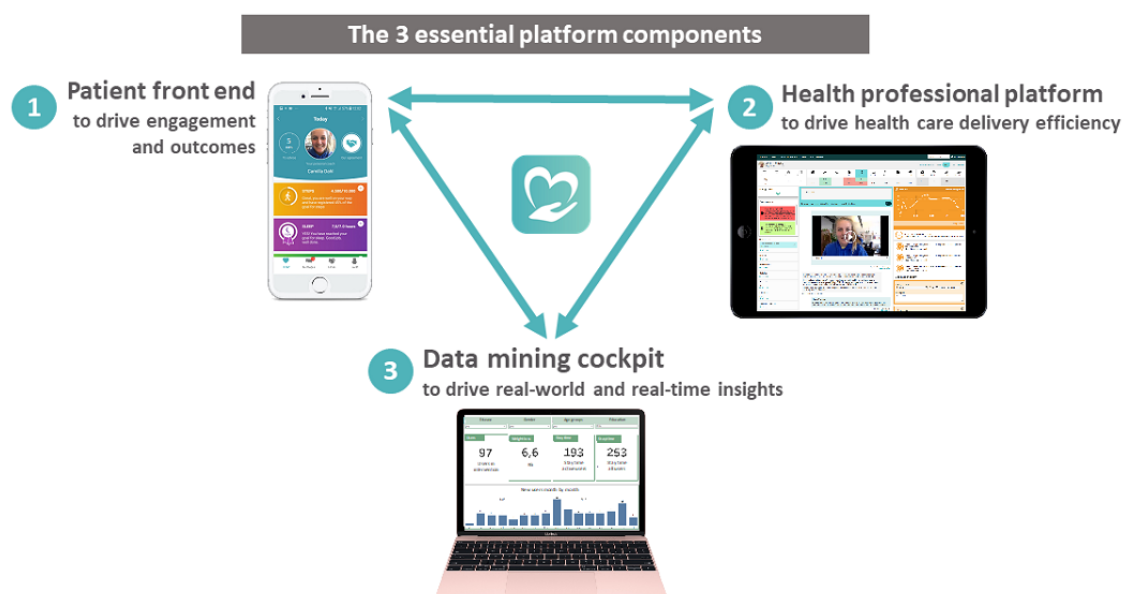
The patients registered their data on a smartphone or logged into a personal profile using the internet (see Figure 2).

The patients filled in a daily record as well as their comments, concerns, and questions to the municipal HCP, who had access to the participant profiles through a control panel. The municipal HCP provided individual asynchronous online consultation according to the patient's needs based on the patient's own registrations. The municipal HCP encouraged and praised goal attainment and sought to maintain the patient motivation. Within the first 3 months, patients were guided by the municipal HCP once every week. In the following 2 months, consultations were provided every second week. After this, guidance took place monthly until 12 months. The following year, the patient proceeded to the retention phase, receiving quarterly consultations described in Figure 3.

Data Analysis

Outcome data were pooled across municipalities, and average findings were reported. We used a descriptive statistics approach to summarize characteristics of the study population. We reported means and SDs. We estimated weight change among diabetes patients in the periods of up to 6, 9, and 12 months. To examine the intervention impact on weight change, we used ordinary least square regression, including age, gender, and initial BMI as confounders. We investigated the effect of potential explanatory variables: number of messages sent by the patient, number of posts written in the forum, and engagement rate, which is the percentage of weeks where a patient actively uses the app out of the total weeks in the intervention. Applying t test and analysis of variance (ANOVA) tests, we compared weight change between male and female patients as well as across 3 age groups: <40 years, 40-59 years, and ≥60 years. Statistical significance was inferred at a 2-tailed $P<.05$. All analyses were completed using Stata version 14.1 (Stata, College Station, TX, USA).

Table 1. *Template for intervention description and replication* checklist for the electronic health lifestyle intervention.

TIDieR[a,b] checklist item	Description
What?	The health care professionals (HCPs) received training in setting SMART[c] goals and digital coaching. Patients receive 1 or 2 personal meetings (face-to-face or digital) with the HCP, followed by asynchronous Web-based consultations based on dialog by means of short message service text message or video. The consultations addressed the patient's registrations, goal setting, and questions regarding diet, exercise, and lifestyle plan and took chronic diseases into consideration. The LIVA app is set up with short explanations on different functions and notifications and reminders to the patients to register and give feedback on the health coaching. The sessions provide the user with information in relation to their status, specific focus on goals, and recommendations on how to improve their behaviors.
eHealth coaching sessions	Included BCT[d] from CALO-RE[e] taxonomy (hereafter referred to as BCT): provide information on consequences of the behavior in *general* and *to the individual*, goal setting: behavior and outcome, action planning, barrier identification or problem solving, set graded tasks, prompt review of behavioral goals, prompt review of outcome goals, prompt rewards contingent on effort or progress toward behavior, prompting generalization of a target behavior, and provide feedback on performance.
Goals and inputs	The goals and inputs described underneath are available to the patient, who can choose his or her focus area, set specific concrete goals, and keep record of specified behaviors by reporting on them on a daily, weekly, or monthly basis. This allows the user and the HCP to follow progress or setbacks as the numbers and registrations get visualized with graphs and curves. All advices from the HCP follow national guidelines from the Danish National Board of Health.
Dietary goals and plans	Dietary goals and plans can be set at many different levels from simple changes aiming at changing 1 meal a day to more complex changes aiming at a completely new diet composition to remedy digestion problems.
Physical activity goals and plans	Goal setting and recording of type and time for executing any given physical activity. The user receives advice and/or video on activities in a variety of contexts to foster physical activity as a more integrated part of the person's life (BCT: provide instruction on how to perform the behavior, prompting generalization of a target behavior, and relapse prevention or coping planning).
Life goals	Goals on a healthy, joyful life as the patient sees it, for example, daily life with less stress, stronger social bonds with friends and family, and coping skills for diseases.
Weight-input	Set current weight and goal for a lower or higher weight and register new measurements on a daily, weekly, or monthly basis.
Steps-input	When downloading the app, the user can accept that their information on steps recorded on a smartphone are imported directly, and tailored messages on progress toward a set goal appear simultaneously (BCT: teach to use prompts or cues).
Pain, sleep, and mood-input	Give daily feedback on pain, sleep, and mood, which can affect the ability to perform a given behavior (BCT: relapse prevention or coping planning).
Smoking-input	Set goals to bring down the number of cigarettes smoked on a daily basis, leading to cessation.
Blood glucose, cholesterol, and lung capacity-input	Keeping a record of specified measures expected to be influenced by the different behavior changes addressed. In LIVA, this includes blood glucose, cholesterol, and lung capacity. (BCT: prompt self-monitoring of behavioral outcome and provide information on consequences of the behavior in *general* and *to the individual*).
Forum	Online forum where the users can exchange knowledge, gain social support, and build new relationships; the health coach can add advices to the forum users (BCT: plan social support or social change).
Who provided?	Health professionals with basic training as nurses, physiotherapist, dieticians, and occupational therapists were performing the health coaching.
How?	Individually delivered via the app or Web.
Where?	Initial personal meeting in the health centers or digital. Then solely Web-based delivery.
When and how much?	The initial consultations with a health coach is estimated to last approximately 45 to 60 min. The following asynchronous eHealth coaching sessions were carried out once weekly in the first 3 months and then for maintenance every third week for the last 9 months. Hereafter, the patient can receive 2 eHealth coaching sessions and use LIVA as a personal behavioral change tool. (BCT: use of follow up prompts).
Tailoring	Every patient received personal eHealth coaching sessions from their designated health coach. The feedback given was based on the patient's inputs on LIVA.

[a]TIDieR: *template for intervention description and replication.*

[b]On the basis of the study by Hoffmann et al [19].

[c]SMART: specific, measurable, agreed upon, realistic, and time-based goals.

[d]BCT: behavior change technique.

[e]CALO-RE: Coventry, Aberdeen, and London-Refined taxonomy [20].

Figure 2. Patient experience using the eHealth intervention.
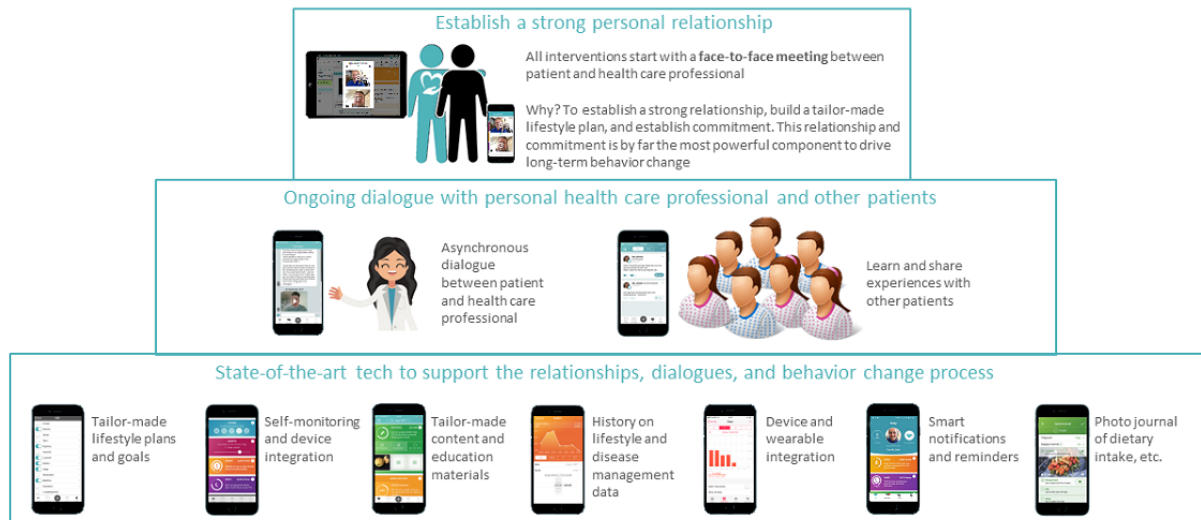
Figure 3. Healthcare professionals experience using the eHealth intervention.
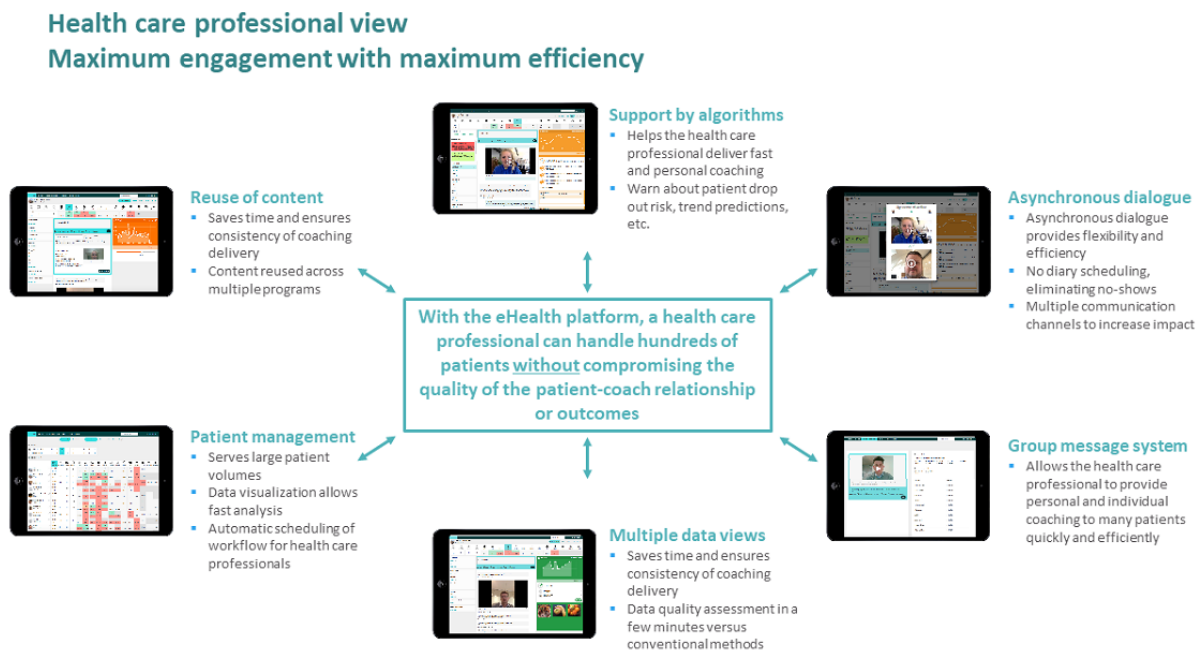
Results

Patients at Baseline

On average, diabetes patients who participated in the program for 90 days or longer were obese at baseline, with 57 out of 103 (55.3%) being females. The study population has on average been in the intervention for 220 days (7.3 months; Table 2).

Observed Weight Change

Majority of the study population, 88 out of 103 participants (85.4%), lost weight, whereas 15 patients (15/103, 14.6%) maintained or gained weight (Figure 4).

According to the examined data, on average, individuals with diabetes reduced their weight by 4.78 kg or 4.3% of their initial body mass, which corresponds to a 1.58-point change in BMI. Female patients lost 4.22% of the initial body mass, whereas male patients reduced their weight by 4.41% (Table 3).

Table 2. Baseline characteristics of the study population.

| Characteristics	Statistics
Individuals (n)	103
Age (years), mean (SD)	55.6 (10.8)
Female, n (%)	57 (55.3)
Weight (kg), mean (SD)	106.8 (18.8)
Body mass index (kg/m^2), mean (SD)	36.0 (5.2)
Duration (days), mean (min, max)	219.9 (92, 365)

Figure 4. Observed weight change among the diabetes patients.
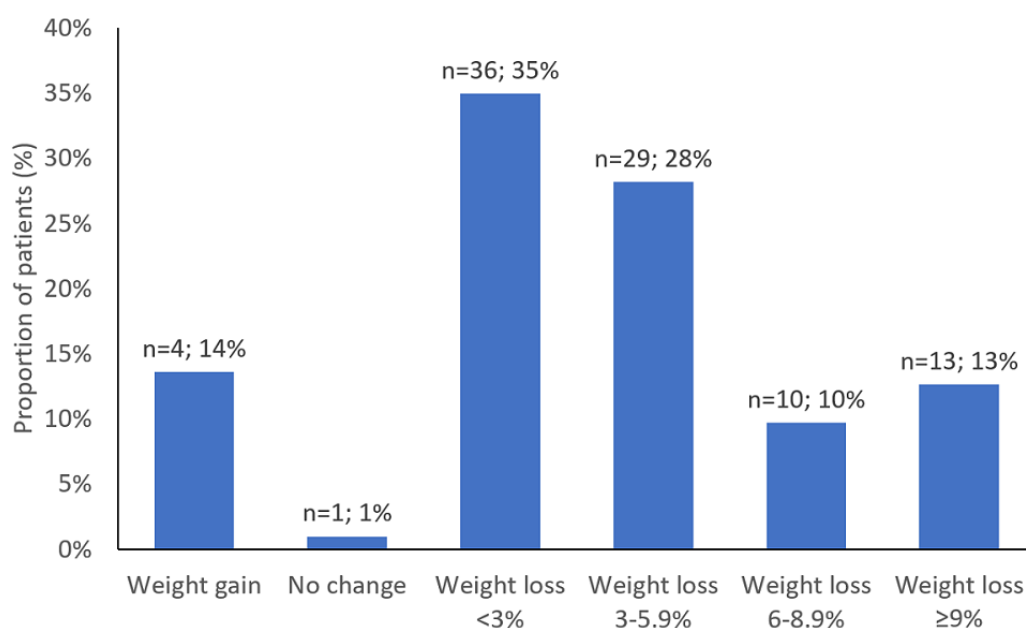
Table 3. Weight change during the intervention according to the observation period (duration).

Characteristics	Duration (90-365 days)	Duration (90-179 days)	Duration (180-269 days)	Duration (270-365 days)
Individuals (n)	103	97	54	39
Female, n (%)	57 (55.3)	53 (55)	31 (57)	21 (54)
Duration (days), mean (min, max)	219.9 (92, 365)	148.8 (92, 179)	240.5 (182, 269)	330.5 (273, 365)
Weight change (kg), mean (SD)	−4.78 (6.67)	−4.31 (5.9)	−6.14 (7.92)	−6.78 (8.1)
Weight change (% of initial weight), mean (SD)	−4.3 (5.93)	−3.9 (5.34)	−5.56 (6.93)	−6.27 (7.64)
Weight change in female	−4.22 (6.83)	−0.91 (6.09)	−5.96 (8.03)	−6.78 (9.12)
Weight change in male	−4.41 (4.63)	−3.9 (4.33)	−5.02 (5.23)	−5.68 (5.67)
Body mass index change (kg/m^2), mean (SD)	−1.58 (2.24)	−1.43 (2.0)	−2.05 (2.67)	−2.24 (2.67)

Figure 5 illustrates the distribution of percentage weight change among the diabetes patients, where negative numbers indicate weight loss and positive numbers indicate weight gain.

The weight change of those individuals who have registered their parameters up to 180 days was −3.9%, for those up to 270 days was −5.56%, and for those up to 365 days was −6.27% (Table 3). Figure 6 illustrates the weight change in kilos per person per day.

Figure 5. Distribution of percentage weight change among the diabetes patients.
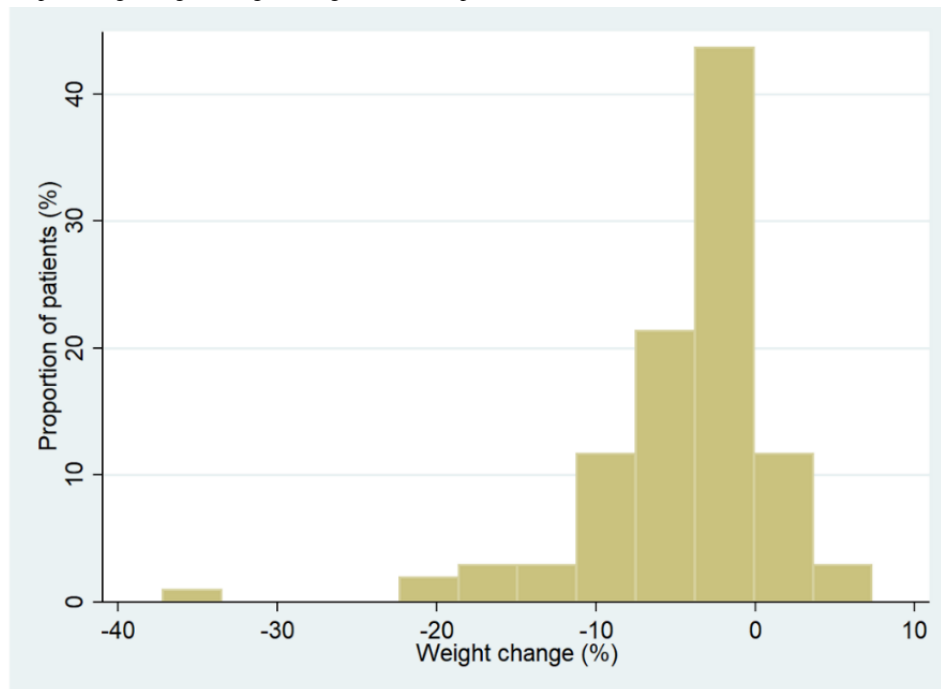
Figure 6. Weight change among the diabetes patients in intervention. Each dot represents a weight change estimated from the weight parameters registered by each diabetes patient. The red line with grey area illustrates prediction from a linear regression of weight change on days in intervention, including the CIs.
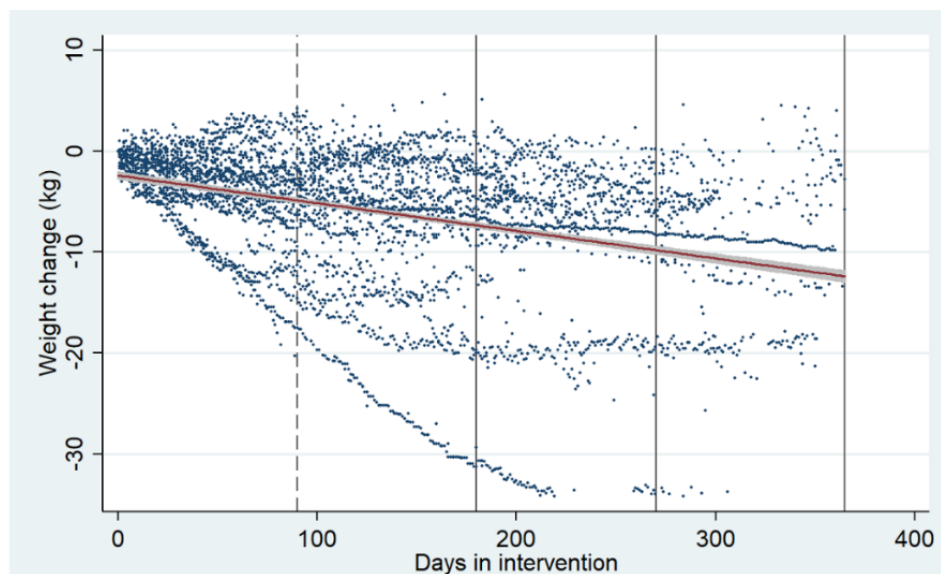
Difference Between Patient Groups

The mean weight change among male patients was –5.04 kg and among female patients was –4.56 kg; the difference of 0.48 kg between the gender groups was not significant (*P*=.72). The observed mean weight change among patients older than 40 years (N=9) was –4.7 kg, 40 years to 59 years (N=56) was –4.9kg, and 60 years or older (N=38) was –4.6 kg. We applied 1-way ANOVA to examine mean weight change between the 3 age groups and found that the difference observed between the age groups was insignificant (*P*=.99).

Impact of Intervention on Weight Change

The results of regression analysis indicate that participation in intervention has a significant impact on weight change, where time in intervention is associated with weight loss, implying that an extra day in intervention corresponds to 16 g weight loss (*P*=.02) or about 480 g per month (Table 4).

The additional explanatory variables were investigated with regard to the impact on weight change (kg). Table 5 presents the outcomes of the linear regression, where number of forum posts and engagement rate (%) are associated with weight loss, but results are statistically insignificant (*P*>.10).

Table 4. Results from regression analyses for prediction of weight change (kg). Regression model summary: N=103; R^2=.108; adjusted R^2=.071.

Explanatory variable	Regression coefficient	P value
Time	−0.016	.02
Baseline body mass index	−0.280	.03
Age	−0.008	.90
Gender	0.519	.69
Constant	8.503	.29

Table 5. Results from regression analyses for prediction of weight change (kg). Regression model summary: N=103; R^2=.120; adjusted R^2=.055.

Explanatory variable	Regression coefficient	P value
Time	−0.013	.03
Baseline body mass index	−0.252	.06
Age	−0.018	.78
Gender	1.079	.43
Sent messages	0.017	.69
Forum posts	−0.131	.29
Engagement	−0.024	.50
Constant	8.503	.29

Discussion

Principal Findings

Results show an average weight loss of 4.8 kg corresponding to 4.3% of initial body weight over a mean period of approximately 7 months. According to regression analysis, the weight loss is significant over time (P<.05). We found that time spent in intervention was the main driver for weight loss. Gender and age did not significantly influence the outcomes, indicating that the intervention effect is not dependent on traditional demographic characteristics, as often anticipated in lifestyle interventions [21].

Despite the anticipated impact of engagement in the app along with forum activity and messaging frequency on weight loss, the insignificant results indicate that motivation within the intervention is not equal to activity and engagement in the digital device. Further research based on a larger sample size would improve the results.

Haste et al found an average weight loss of 5.4 kg for the ones who completed a 12-month Web-based weight loss intervention for men with type 2 diabetes in a previous Web-based version of the collaborative eHealth intervention in a pilot randomized controlled trial in a municipality setting [6]. Other eHealth coaching programs among diabetes patients have found weight reductions of 6.8% to 7.5% of body weight among completers after 6 to 12 months [22-24]. A review concluded a mean reduction in body weight of 3.73 kg after 12 months among 13 studies, analyzing the effect of BCTs on diet and physical activity in type 2 diabetes [25]. This indicates that the validity of the trends observed is promising, especially given the modest investment compared with traditional lifestyle change or exercise interventions.

This study evaluates the effects associated with a real-life eHealth lifestyle coaching intervention (LIVA) in 8 Danish municipalities. The observational design allows for data to reflect a real-life setting based on a substantial number of observations; results show clear tendencies of significant self-reported weight reduction among diabetes patients.

Within the scope of this study, we conducted an extensive review of available literature that observes the impacts of weight reduction among the obese diabetes patients on the costs of diabetes [26-31]. Following the literature review, we expect that a 1% reduction in weight among diabetes patients corresponds to 3.1% decrease in societal costs of diabetes in Denmark, which were previously estimated by Sortsø et al [32]. The average weight loss of 4.3% among the diabetes patients within the cohort has a potential to reduce the annual diabetes costs of a single diabetes patient by 13.33%, corresponding to Euro 2676 savings per diabetes patient per year, compared with the no-intervention scenario (the costs of intervention were not included). Subtracting the implementation and running costs of the intervention, the implementation was found to be cost-effective in a municipal perspective already after 1 year of implementation [33].

Preventive strategies within diabetes have gained ground the past decade, for example, the Diabetes Prevention Program in the United States [22,24,34]. The National Health Service also launched a National Diabetes Prevention Program (NDPP) in 2016, which covered 75% of the nation in April 2017 [35,36]. These programs were initiated based on the expectation that lifestyle change among people at risk of or early in their diabetes will be effective in reducing the incidence of diabetes as well as late complications, thereby reducing costs. The economic assessment of the NDPP is undertaken from a 20-year perspective because of the disease structure of diabetes with

risk of complications, and hence costs, increasing over time [37].

Limitations of the Study

Self-reported data are always subject for reporting bias. Other studies have, however, shown that self-reported data in Web-based eHealth solutions are valid [38]. As we observe a weight difference as our outcome, we assume reporting bias to be equal for both baseline and end data. An objective measurement and improved registration of comorbidities could strengthen the data and allow the distribution of diabetes patients across complication groups.

This study reflects a natural experiment in the sense that we observe a running program implemented in a real-life municipal setting. This is a strength as well as a limitation in relation to disentangling the effect of the program. In a longer follow-up, analysis with more observations within municipalities would provide valuable insights.

Long-term evidence on sustainability of results is needed within this area. Hence, a register-based study with observation of actual costs of participants over a longer follow-up period and subsequent comparison with control population would provide important new knowledge. Furthermore, as we observe different effects of the program across municipalities, there is a need for in-depth analysis within each municipality to investigate what is decisive for the effect.

Conclusions

We found that the collaborative eHealth tool significantly reduced weight among diabetes patients, on average 4.3% of the initial body mass with potential substantial cost savings. This study is based on a study population consisting of 103 individuals with diabetes, and it brings forward evidence of a positive effect of a running municipal secondary preventive offer that targets diabetes patients. Our study establishes a framework for further evaluation of eHealth tools where new data from longer follow-up can be examined to strengthen conclusions from this study.

Perspectives and Implications

The findings in this study are of relevance for all HCPs working with primary and secondary prevention of diabetes. Collaborative eHealth lifestyle coaching tools offer promising new opportunities for successfully changing diabetes patients' lifestyles. However, much remains unknown in this new era of eHealth possibilities. The results presented in this study are of importance, stressing that with a relatively modest personal resource investment, a collaborative eHealth lifestyle coaching tool can enable tailored coaching, resulting in significant weight losses among diabetes patients. We believe that these preliminary results show promising tendencies; however, there is a way yet to demonstrate sustainability of the weight loss attained as well as specific cost savings. We will investigate these issues along with long-term data arriving.

Conflicts of Interest

The Institute of Applied Economics and Health Research Aps (ApHER) received a grant from LIVA Healthcare A/S to conduct the analysis. AK, ME, and CS were employed at ApHER. CJB owns stocks in LIVA Healthcare A/S, the company that developed parts of the technical platform and hosted some of it during the study. DH is employed by LIVA Healthcare A/S.

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Abbreviations

ANOVA: analysis of variance
ApHER: Institute of Applied Economics and Health Research Aps
BCT: behavior change technique
BMI: body mass index
eHealth: electronic health
HCP: health care professional

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Perceptions and Acceptability of Text Messaging for Diabetes Care in Primary Care in Argentina: Exploratory Study

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Abstract

Background: Engagement in self-care behaviors that are essential to optimize diabetes care is challenging for many patients with diabetes. mHealth interventions have been shown to be effective in improving health care outcomes in diabetes. However, more research is needed on patient perceptions to support these interventions, especially in resource settings in low- and middle-income countries.

Objective: The goal of the research was to explore perceptions and acceptability of a short message service (SMS) text messaging intervention for diabetes care in underserved people with diabetes in Argentina.

Methods: A qualitative exploratory methodology was adopted as part of the evaluation of a program to strengthen diabetes services in primary care clinics located in low-resource settings. The diabetes program included a text messaging intervention for people with diabetes. A total of 24 semistructured telephone interviews were conducted with people with diabetes.

Results: Twenty-four middle-aged persons with diabetes were interviewed. Acceptability was considered adequate in terms of its actual use, frequency, and the role of texts as a reminder. We found that text messages could be a mediating device in the patient's learning processes. Also, being exposed to the texts seemed to help bring about changes in risk perception and care practices and to function as psychosocial support. Another relevant finding was the role of text messaging as a potential facilitator in diabetes care. In this sense, we observed a strong association between receiving text messages and having a better patient-physician relationship. Additionally, social barriers that affect diabetes care such as socioeconomic and psychosocial vulnerability were identified.

Conclusions: Our findings show positive contributions of a text messaging intervention for the care of people with diabetes. We consider that an SMS strategy has potential to be replicated in other contexts. However, further studies are needed to explore its sustainability and long-term impact from the perspective of patients.

Introduction

Background

Diabetes mellitus is a leading cause of death worldwide with marked regional variation [1], resulting in a significant public health problem [2,3]. The global prevalence of diabetes in adults was 8.8% in 2015 and is predicted to rise to 10.4% by 2040; 81.1% of undiagnosed persons live in low- and middle-income countries (LMIC) [4].

In Argentina, the prevalence of diabetes increased from 8.4% to 9.8% between 2005 and 2013. In addition, an increase in diabetes mellitus–related deaths was observed in people aged older than 25 years [5,6].

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Persons with diabetes are advised to have periodic visits with health providers and engage in self-care behaviors such as following a diet, taking medications, engaging in regular physical activity, and self-monitoring blood glucose [7,8]. These aspects of diabetes self-management are essential to optimize diabetes care, improve health outcomes, and prevent long-term complications [9,10]. However, many people find these behaviors difficult to achieve and maintain [11]. In fact, only 3.8% of Latin American patients with type 2 diabetes included in the International Diabetes Management Practice Study (IDMPS) achieved the recommended treatment goals of glycated hemoglobin <7%, low-density lipoprotein cholesterol <100 mg/dL, and blood pressure ≤130/80 mm Hg [12].

Patients need support from health care professionals to achieve these goals and, given the increasing prevalence of type 2 diabetes in LMIC, there is a need for innovative and effective ways to deliver self-management support interventions [13] between clinical encounters in resource-constrained health care systems. In this sense, interventions delivered via mobile phone short message service (SMS) text messaging have the potential to improve care with chronic diseases like type 2 diabetes [14-16] because unlike other technologies, mobile phones have a high penetration among low-income groups.

Although mobile health (mHealth) interventions have been shown to be effective in improving health care outcomes in diabetes [17-20], evidence about the likely uptake, best strategies for patient engagement, efficacy or effectiveness, and costs should guide the adoption of new technologies. Research on mHealth implementation is limited, and further research into these issues is needed. Also, there are significant information gaps regarding long-term effects, participant and provider acceptance, behavioral outcomes, costs, and the risks of such interventions with a focus in LMIC [21].

Latin America is in the process of expanding information and communication technologies and seeing an increase in the mobile network penetration [22]. The high prevalence of mobile phone availability, access, and use in low-resource settings offers a context in which it is possible to use these devices to improve health care delivery.

This study was conducted as part of a program to strengthen diabetes care in primary care clinics that include an mHealth intervention to support diabetes care for underserved populations.

Diabetes Care Program

A diabetes care program was implemented in 20 primary care clinics (PCCs) within the national public system network located in low-income settings from 5 departments of the province of Corrientes, Argentina [23,24]. These clinics provide health care services and essential chronic care medication free of charge to persons with diabetes living in the catchment area. The program was developed by the Institute for Clinical Effectiveness and Health Policy (IECS), an academic organization, in collaboration with the Ministry of Public Health of the Province of Corrientes.

The intervention implemented by the program lasted 12 months and included (1) primary care team training for the implementation of clinical practice guidelines, (2) development

of a Diabetes Registry to monitor and follow the patients up at the clinics, and (3) a text messaging intervention tailored to patient characteristics.

A total of 947 persons with diabetes were enrolled in the Diabetes Registry, of whom 62.3% (590/947) were women and 92.9% (880/947) had type 2 diabetes. The majority (830/947, 87.6%) had access to a mobile phone and agreed to receive SMS text messaging. Participants received an average of 53 texts during the study period. The study protocol is reported elsewhere [24], and the results of the program evaluation will be reported in future publications.

The Text Messaging Intervention

- One-way weekly texts were sent to people with diabetes included in the Diabetes Registry until the participant came in for the 12-month follow-up visit.
- Texts were developed and validated using a methodology that evaluated understanding and appeal of each SMS text message using a 7-item questionnaire [24,25].
- Educational messages and reminders to address issues related with adherence to antidiabetic treatment, lifestyle modification, diabetes education, and facilitation of clinical encounters with the primary care team were included.
- Texts were tailored to baseline patient characteristics addressed by primary care physicians at the clinics (see Multimedia Appendix 1 for examples of text messages).
- A Web-based platform was developed to deliver texts.
- Texts were customized according to baseline characteristics and were sent in a fixed order.

To our knowledge, no study has been published in the region describing the experiences of people with diabetes with a text messaging intervention operating in routine clinical practice in PCCs located in low-resource settings. The aim of our study was to explore the perceptions and acceptability of an SMS text messaging intervention for diabetes care in underserved people with diabetes in Argentina.

Methods

Design and Study Participants

A qualitative and interpretative phenomenological study [26] of participant perceptions, experiences, and opinions of an SMS texting intervention was conducted in accordance with qualitative research guidelines during the implementation of the diabetes care program [27,28].

We used a combination of convenience and saturation sampling to enroll participants in the program. Study participants were selected from the Diabetes Registry if they met the inclusion criteria: adults aged 18 years and older with a diagnosis of type 2 diabetes who received care from selected clinics, had access to a mobile phone, and received texts during the implementation of the program. We included participants from a variety of departments to guarantee geographical coverage. The final sample size consisted of 24 informants between ages 39 and 66 years.

Data Collection

An independent research team comprising researchers from the IECS led the qualitative study. No health care personnel were involved in the recruitment or interviewing process. Between March and October 2017, semistructured telephone interviews (with an average duration of 30 minutes) were conducted with study participants.

Semistructured interview guidelines, adapted during the data collection process, were developed based on the study objectives, including sensitive questions to identify emergent themes (see Multimedia Appendix 1 for the semistructured interview guideline, available only in Spanish).

Data collection stopped when data saturation was reached for the dimensions found, and it was judged that no new significant or relevant information emerged from the interviews.

Data Analysis

Written transcripts of the interviews, which compounded the unit of analysis, were classified and then codified according to the study objectives and the dimensions addressed, constituting a single corpus of information.

The written transcripts were entered into ATLAS.ti version 7 (ATLAS.ti Scientific Software Development GmbH) software combined with the manual technique of information coding. Analytical dimensions were identified as constructs for the description of findings.

Finally, data were abstracted and interpreted through content analysis [29]. As part of the analysis, direct quotations representative of the participants' opinions were selected and included in this manuscript to illustrate our findings. In order to protect the identity of the informants we only provide information on age and gender.

Ethics

This study was reviewed and approved by the Institutional Review Board of the Hospital Italiano de Buenos Aires (CIE No. 2641, 22/10/2015). Participation in the study was voluntary. All participants signed an informed consent, and the confidentiality of the information was guaranteed.

Results

Characteristics of the Study Participants

Twenty-four adults aged 39 to 66 years were interviewed; 54% (13/24) were women. Selected participants had similar sociodemographic characteristics to those included in the diabetes program (Table 1).

The median diabetes duration was 7 years (interquartile range 4 to 10). As regards comorbidities, 15 participants (62%) had hypertension, 10 (42%) had dyslipidemia, 15 (62%) were obese, and 5 (21%) had at least one macrovascular or microvascular complication. At the time of the interview each participant had received a mean of 55 text messages during the program.

Findings Dimensions

From the analysis of participant discourse, we developed a qualitative framework about contributions of text messages to diabetes care (Figure 1). We included all the dimensions that emerged from the collected data regardless of the number of participants who mention them. We did not perceive differences in opinions associated to participant characteristics (clinic or sociodemographic).

Table 1. Sociodemographic characteristics of the population under analysis (N=24).

Characteristics	Value, n (%)
Gender	
Female	13 (54)
Male	11 (46)
Age in years	
39-60	16 (67)
>60	8 (33)
Level of education	
7 years of schooling or less	13 (54)
8-12 years of schooling	10 (42)
>12 years of schooling	1 (4)
Health coverage, yes	12 (50)

Figure 1. Emerging framework from our proposal.
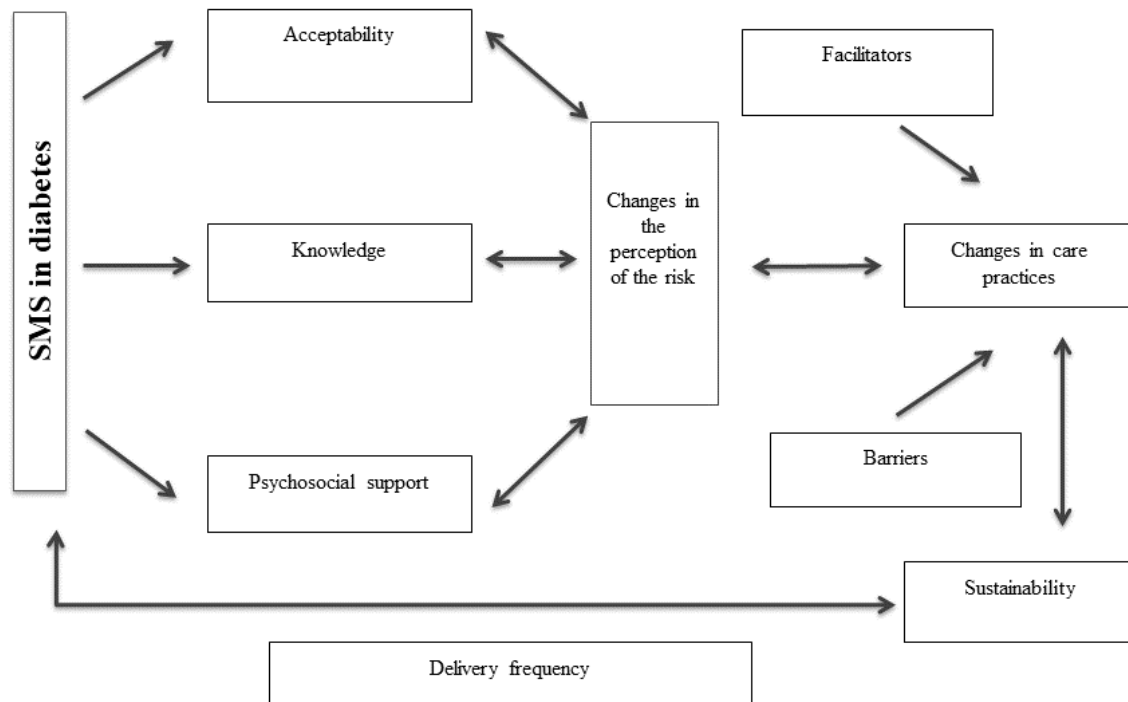
General Experience With the Text Messaging Intervention

The interviewed population gave some texts more attention than others (Multimedia Appendix 2). The most remembered messages were related to foot care: diabetic foot prevention, avoidance of infections, guidance on footwear, adequate foot care hygiene recommendations, and recommendations about when to see a physician.

> *Yes, [I remember] a message that was about the diabetic foot. It said that we have to wear footwear all the time because it is a silent illness.* [Woman, 51 years]

Messages about recommendations for a healthy diet were also well remembered. In this sense, study participants appreciated recommendations on the consumption of fruits and vegetables.

Messages to promote medical visits and foster compliance with diabetes medication and glycemic control were pointed out by participants less frequently. Messages about physical activity were not mentioned by participants.

Acceptability of the Text Messaging Intervention

A set of characteristics was used to assess acceptability of the text messages. Components that emerged from the speeches analyzed were usability, frequency preferences, and a reminder function.

As for usability, participants indicated that they always opened and read the messages, and they ensured they had no problems with opening and reading them. Some participants expressed that they saved them in their phone devices or transcribed them in notebooks. They also stated that messages were very useful and that they felt happy and grateful to receive them. A weekly frequency of messages was perceived as adequate and well accepted. Additionally, a significant number of interviewees mentioned the reminder function of the text messages.

> *If there is one that interests me I'll write it in a notebook...I keep the ones that I like the most in a notebook, so that I don't forget.* [Woman, 52 years]

In addition, some factors were identified that might influence the sustainability of diabetes care such as the relationship established with the referring physician and proximity to the PCC (Multimedia Appendix 2).

Text Messaging Impact on Knowledge About Diabetes

Subjective contents that emerged were related to changes in knowledge about diabetes before and after being exposed to text messages. The text works as a mediating device that facilitates the patient's learning processes and promotes the dissemination of the acquired knowledge when messages are shared with family and friends (Multimedia Appendix 2).

Text Message Contribution to Psychosocial Support

All participants expressed feelings associated with text messages during the course of their disease. Some reported that texts gave them a feeling of comfort and tranquility, and they valued the presence of text messaging as a confirmation that somebody remembers their illness and takes care of them without personally knowing them.

> *I feel more accompanied, I feel calmer. At least, someone who always remembers me because when you receive something in your cellphone, in your phone, you feel more comfortable, more peaceful.* [Woman, 63 years]

In addition, we observed that text messages impacted on the process of socialization of persons with diabetes. Furthermore, some interviewees reported that they shared text messages with a relative who also had diabetes, highlighting the role of texts as an educational device for transferring information (through oral communication and/or forwarding of messages; Multimedia Appendix 2).

Effect of the Text Messaging Intervention on Changes in Risk Perception

Most of the interviewees mentioned some change in the perception of risk in diabetes after being exposed to text messages. This was reflected by emphasizing some associations between receiving messages and being more aware of diabetes care (Multimedia Appendix 2).

> *Yes, almost all [the messages] because it makes me aware, careful, and tells me how to take care of myself. We become conscious of what we suffer from.* [Man, 59 years]

Effect of the Text Messaging Intervention on Changes in Diabetes Care Practices

Some changes in preventive and curative diabetes care practices were highlighted. We observed some changes regarding health care behaviors related to diabetes that could be linked to receiving text messages. These changes were mainly concentrated around healthy eating, weight loss, visits to the doctor, taking medication, physical activity, foot care, and attending medical supervision.

To a lesser extent, some patients stated that they were visiting their doctor more frequently. During these visits, they showed the doctor their sugar levels, had their feet checked, and had their vaccination scheme checked. Furthermore, the interviewees said that they now have better control of glycemia, glycated hemoglobin, and blood pressure values. Changes in physical activity, such as walking, were not much reflected in the perceptions of the interviewees.

Participants relayed that although they were willing to comply with diabetes care recommendations provided by text messaging, there were some barriers to diabetes care such as socioeconomic vulnerability, difficulties in accessing medical supplies (such as test strips or glucose meter) and healthy food, and psychosocial vulnerability (stress, conflicts in the family).

> *For me it's fine, but the more support the better. You know why? Because I am a single parent, that is to say, mom and dad all in one...understand?* [Woman, 47 years]

Another relevant result is the role of the text message as a possible facilitator in the interaction with the PCC physicians regarding diabetes care. In this sense, some patients shared the messages they received with their physicians (Multimedia Appendix 2).

Discussion

Principal Findings

The qualitative approach used in this study allowed us to explore the perceptions of the people with diabetes that received a text messaging intervention. Our findings showed that a text messaging intervention with educational messages and reminders within the framework of a diabetes care program contributed positively to diabetes care and was accepted by people with diabetes with low educational level who live in low-resource settings.

Comparison With Prior Studies

In agreement with our findings, Leon et al [30] showed that weekly texts were acceptable for persons with hypertension. Hacking et al [31] also found a positive attitude toward this intervention in patients with hypertension.

Messages that were recalled and remembered came from different domains. However, texts for foot care were the most remembered; this may be due to certain cultural valuations, previous knowledge, and the connotations that diabetic foot and its physical consequences [32-34], especially amputation, have in our society.

Exploring the most remembered messages for persons with diabetes allowed us to highlight the impact of messages with different content. This hierarchy, where informants gave some texts more attention than others, could be associated with certain cultural, symbolic, and evaluative patterns around the disease and its consequences.

In our study, participants perceived an increase in their knowledge of diabetes when exposed to text messaging. In accordance with previous studies [17,18], texts acted as a mediator in the patients' learning processes facilitating the construction of significant learning [35].

The psychosocial support effect of text messaging in diabetes was important since it allows us to think about actions oriented toward a comprehensive approach to this chronic condition [36] and to contribute to the overall quality of life in persons with diabetes. Something similar was found in a study by Kwan et al [19]: texting services may help recognize distress and understand its effects on diabetes control, quality of life, and relationships with friends and family.

A distinctive fact that arises from this work and that has not been extensively addressed by other authors concerns the socialization effect of texts. In our study, informants stated that they shared the content of the texts with their family and friends.

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In this sense, we found that text messaging generates new ways of interaction, communication, and learning.

Risk perception is a critical determinant of health behavior [20]. In this regard, positive changes in risk perception were observed in patients after being exposed to text messages.

This was reflected when participants stated that they were more aware of diabetes when receiving the messages. Other studies that explored this effect of text messaging in conditions like HIV and in preventive programs [37,38] showed similar results.

Texts worked as a facilitator of the relationship between the people with diabetes and the health care team. Perhaps the texts alone are not responsible for this as text messaging intervention was implemented within the framework of a diabetes care program that also contemplated primary care training in diabetes management, education, and follow-up of patients. A relationship was observed between receiving texts and interacting with the referring physician. Similarly, this association was found in other studies aimed at patients with chronic diseases [30,36].

Social barriers to diabetes care were diverse. Although the participants interviewed received the texts adequately, we detected the presence of barriers that negatively impacted their self-management. These barriers (limited economic resources and lack of social support) have also been identified in other studies [39]. Additionally, qualitative study of cultural factors and diabetes found that social support may promote diabetes self-care but may also act as a barrier to diabetes management [32].

It is necessary to design interventions with an eye toward the limitations and context in which they will be implemented. Thus, qualitative research is a critical step in designing and implementing effective, feasible, and sustainable interventions.

Some studies have postulated that interventions with text messaging in LMIC have a positive impact on chronic disease management, including diabetes [14,40-43]. A qualitative perspective that takes the perception of patients is essential for the adoption and scaling up of these interventions. However, published studies on this subject are limited [32,44].

Several qualitative studies focused on other chronic noncommunicable diseases, such as hypertension, asthma, cervical cancer, and obesity, among others [30,44-47], in LMIC.

From the analysis of participant discourse, we developed a framework to explicitly theorize about contributions of texts to diabetes care. This theoretical framework has potential because it arises from the data. Also, our findings were similar to other frameworks previously published about chronic conditions based on the information, motivation, and behavioral skills model of health [48]. This leads to the need for greater knowledge production in this area, in particular from a diverse patient perspective [36].

Strengths and Limitations

Among the limitations of this study may be those derived from qualitative research itself, such as lack of generalizability to other populations. We are aware that there may be a selection bias of respondents since the persons who responded may be more interested than others in the subject. However, we tried to minimize these biases by including persons of different ages, sex, and place of residence.

We were aware of the possibility of obtaining complacency bias as well. In order to minimize this bias, we used indirect and generic questioning, allowing respondents to project their own perspectives.

Finally, one of the strengths of our study was our exploration of subjective elements in persons with diabetes using a pragmatic and explanatory approach to better understand the experiential processes of this type of intervention.

Conclusions

The study findings provide empirical evidence on the acceptability and value of text messages for diabetes care. We identified subjective elements of the SMS text message intervention such as adequate acceptability related to the frequency and content of the messages. Texts were found to be a source of diabetes knowledge and psychosocial support for people with diabetes. We also observed changes in risk perception and diabetes care practices. The knowledge gained in this study may reinforce the importance of adding an mHealth component like text messaging to programs for diabetes management implemented in low-income settings.

Conflicts of Interest

None declared.

Multimedia Appendix 1

List of examples of short text messages and semistructured interview guideline.

[PDF File (Adobe PDF File), 90KB - diabetes_v4i1e10350_app1.pdf]

Multimedia Appendix 2

Perceptions and acceptability about short message service.

[PDF File (Adobe PDF File), 101KB - diabetes_v4i1e10350_app2.pdf]

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Abbreviations

IDMPS: International Diabetes Management Practice Study
IECS: Institute for Clinical Effectiveness and Health Policy
LMIC: low- and middle-income countries
mHealth: mobile health
PCC: primary care clinic
SMS: short message service

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Original Paper

Appropriation of Mobile Health for Diabetes Self-Management: Lessons From Two Qualitative Studies

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Abstract

Background: To achieve clarity on mobile health's (mHealth's) potential in the diabetes context, it is necessary to understand potential users' needs and expectations, as well as the factors determining their mHealth use. Recently, a few studies have examined the user perspective in the mHealth context, but their explanatory value is constrained because of their limitation to adoption factors.

Objective: This paper uses the mobile phone appropriation model to examine how individuals with type 1 or type 2 diabetes integrate mobile technology into their everyday self-management. The study advances the field beyond mere usage metrics or the simple dichotomy of adoption versus rejection.

Methods: Data were gathered in 2 qualitative studies in Singapore and Germany, with 21 and 16 respondents, respectively. Conducting semistructured interviews, we asked respondents about their explicit use of diabetes-related apps, their general use of varied mobile technologies to manage their disease, and their daily practices of self-management.

Results: The analysis revealed that although some individuals with diabetes used dedicated diabetes apps, most used tools across the entire mobile-media spectrum, including lifestyle and messaging apps, traditional health information websites and forums. The material indicated general barriers to usage, including financial, technical, and temporal restrictions.

Conclusions: In sum, we find that use patterns differ regarding users' evaluations, expectancies, and appropriation styles, which might explain the inconclusive picture of effects studies in the diabetes mHealth context.

Introduction

Background

Diabetes has increasingly become a major burden for industrialized societies, with rising health care costs and mortality rates pressuring governments globally to address this problem [1,2]. These governments have finally started to recognize the problem's seriousness. Singapore, the first country that we examined, has the second-highest diabetes prevalence rate after the United States [3], and it launched a war on diabetes in 2016. Germany, the second country that we examined, ranks third for diabetes-related health expenditures worldwide [2,4].

With the rapid growth and ubiquitous availability of mobile phones, mobile health (mHealth), that is, "the use of mobile communications for health information and services" [5], can

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potentially contribute to improving health promotion, disease prevention, and disease self-management [6-10]. In the diabetes context, functions such as messaging and chatting with health care providers, connections to external devices (eg, heart-rate measurement and monitoring of blood glucose or blood pressure), and support of medication, as well as tracking physical activity or nutrition behavior via mobile apps are discussed [11,12].

Up to this point, research has mainly focused on mHealth's effects, indicating not only promising results overall [13,14] but also contradictory empirical evidence [15-19]. Even a recent systematic review concluded that research is still too heterogeneous and somewhat too low in methodological quality to "provide reliable evidence of effects for stakeholders" [12]. To gain a clearer picture of mHealth's potential in the diabetes context, it is necessary to understand potential users' needs and expectations, as well as the factors determining their mHealth use. In recent years, more and more studies have dealt with the user perspective in the mHealth context [20-39]. However, most of these studies have fallen short in their ability to explain more than just adoption factors.

Our goal is to describe different patterns of everyday life integration that go beyond mere usage metrics or the simple dichotomy of adoption versus rejection [40]. To achieve this goal, we draw on the mobile phone appropriation (MPA) model [41] as our theoretical frame. Empirically, we conducted semistructured interviews with diabetes patients in Singapore (study 1) and Germany (study 2). Study 1 identified relevant functional, normative, symbolic, and restriction evaluations tied to diabetes app use, whereas study 2 complemented these evaluations for mHealth appropriation and identified supplemental patterns of evaluation, use, and meta-communication.

Mobile Health and Diabetes Self-Management

Current extant research on mobile devices' and services' effects on health outcomes often focuses on SMS text message interventions [14,42]. Increasingly, studies have concentrated on smartphone apps' effects on diabetes self-management [12,13,15]. However, their results are diverse, ranging from positive effects on diabetes outcomes, for example, hemoglobin A_{1c} reduction [43], to limited or no effects [44,45]. Moreover, recent systematic reviews are not consistent but reveal positive effects overall [13,14]. Studies have increasingly tried to specify effects by varying message design and tailoring messages to users' needs [46-49], with promising results. However, also in this context, a clear picture cannot be drawn so far. This may be explained, at least partly, by an overly simplistic idea of use and effects. Using apps or receiving certain messages does not

tell us how users interact with apps and interpret their functions [18].

Thus, the need exists for a better understanding of actual everyday-life use and mobile devices' integration into diabetes self-management. To increase our knowledge about mHealth's role in the diabetes context, we need to ask how, why, and for what purpose patients use mobile devices for diabetes self-management and which motives, perceptions, and expectations drive their use.

Primarily, the answers to these questions require that we define what we mean by *use*. In extant literature, *use* has been used quite heterogeneously, describing all kinds of processes and subprocesses in decision and implementation phases, as defined by Rogers' [50] innovation-decision process. These 2 stages help distinguish between 2 broad areas of use: first, Rogers describes the decision stage (adoption), in which the overall question of use versus nonuse (ie, adoption vs nonadoption) is tackled. The second phase of implementation (appropriation) deals with the question of everyday-life integration and actual use patterns [50,51].

In recent years, more and more studies have focused on mHealth adoption, drawing mostly on the technology-acceptance model (TAM) [24,25,27,33,37,51,52] or its successor, as well as the unified theory of acceptance and use of technology (UTAUT) [30,35,38,39,53], to explain influences on the adoption decision. However, only a few studies have considered an implementation or appropriation perspective on mHealth use, mostly focusing on continued use in contrast to the single-adoption decision. These studies fail to consider the multifaceted patterns of everyday-life integration [21,26,37].

In the diabetes context, most studies that concentrate on the implementation process are rather descriptive in nature, examining frequency of use or expectations regarding diabetes apps [20,22,29].

Appropriation of Mobile Media

The MPA model [41] provides a theoretical framework with which to analyze the appropriation of mobile media as a process (Figure 1), not only in general but also in specific contexts [54]. The model integrates concepts of technology adoption, for example, diffusion of innovations [50], theory of planned behavior [55], TAM [52], and UTAUT [53], with conceptualizations of the actual use and implementation of technological innovations into users' everyday lives. On the basis of cultural studies [56,57] and the domestication approach [58], Wirth et al [41] term this process *appropriation*, emphasizing users' active co-construction of meaning, thereby overcoming the *binary logic of adoption* [40].

Figure 1. The mobile phone appropriation model (simplified).
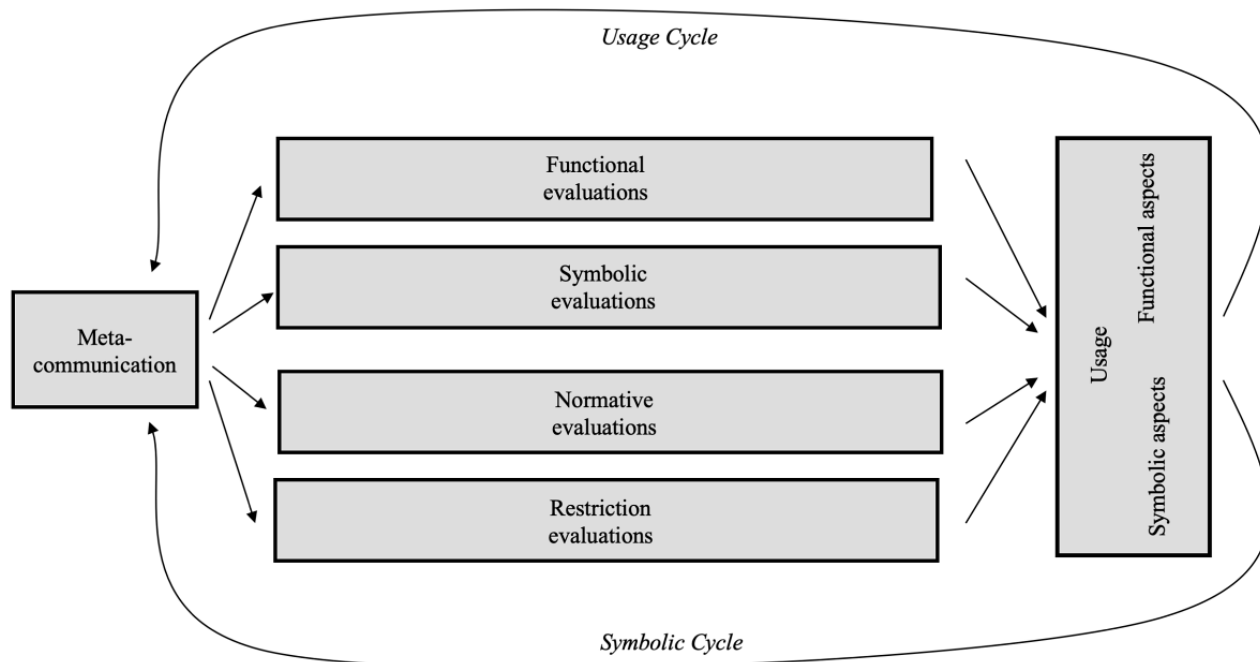
The MPA model conceptualizes appropriation as a creative and active process, resulting in various use patterns by individual mobile-media users. Consequently, behavior is differentiated in sub-constructs in the MPA model, comprising symbolic and functional aspects. The functional aspects represent the variety of uses, for example, highlighted in research on the basis of the uses and gratifications approach. By adding symbolic aspects such as prestige, the MPA captures the concept and extent of observability [50], making the choice and use of mobile media a continuous statement about oneself in public [59]. Functional, symbolic, normative, and restriction evaluations influence these use dimensions. Functional and symbolic evaluations represent users' beliefs about the functional and symbolic aspects of their future mobile-media behaviors. Normative evaluations refer to their beliefs and judgments about social norms related to their future behavior. Restriction evaluations—comprising financial, technical, cognitive, and temporal factors—represent users' beliefs about constraints hindering their future mobile-media behaviors. Restriction evaluations find resonance with the information communication technologies for the health care model used in mHealth studies [60,61], which propose economic, technological, infrastructural, and sociocultural barriers.

In addition, the MPA model integrates meta-communication, that is, the impact of communication on communication technologies. As users communicate about their respective uses of mobile media and observe others' behaviors, this meta-communication influences their future behaviors. Consequently, the MPA model is conceptualized as a cycle, with the appropriation being a constantly renewed process. Functional and symbolic mobile uses are not only the results of behavioral, normative, or restriction beliefs but they also become the basis of those beliefs [62].

So far, the MPA model has been adapted successfully to the mHealth context in 1 study examining patterns in nutrition-app

appropriation [63]. On the basis of a Web-based survey of nutrition app users, the study identified 4 distinct appropriation types: supported, indifferent, health-conscious, and socializer. These types differed mainly regarding (1) the support they received from their social peers for their app use, (2) their personal attachment to their app use, and (3) app use for socializing (and competition). Thus, we see great potential in using the MPA model as a theoretical framework to gain insight into the appropriation processes of mobile services and devices for diabetes self-management and ask these research questions (RQs):

> *RQ1: Which specific functional, symbolic, normative, and restriction evaluations are relevant in the context of mHealth appropriation for diabetes self-management?* [study 1]
>
> *RQ2: What role does meta-communication play in mHealth appropriation for diabetes self-management?* [study 1]
>
> *RQ3: Which patterns of mHealth appropriation can be found in the context of diabetes self-management?* [study 2]

To answer these questions, we carried out 2 related yet independent studies that focused on (1) different aspects of the appropriation process and (2) 2 different cases (Singapore and Germany). Study 1 lays the foundation for investigating app appropriation, and study 2 expands this notion by looking at the broader picture of mHealth for diabetes self-management.

Methods

Study 1 Method

Study 1 (Singapore) focused on the appropriation and use of diabetes-specific apps for self-management (*diabetes apps*). These apps are designed specifically to support diabetes

self-management, including tools for blood sugar monitoring and direct feedback (diabetes log books, eg, *Glyco App*), diabetes information (eg, *MySugr Academy*), or food databases (for counting carbohydrates to adjust insulin, eg, *the Singaporean Health Promotion Board's food database*). We carried out 21 semistructured, face-to-face interviews [64,65] (approximately 1 hour each, in English) with Singaporean type 1 and type 2 diabetes (and prediabetes) patients between December 2015 and September 2016. Singaporean diabetes-support groups (Diabetes and Diabetic Society of Singapore) were used to contact diabetes patients. The participants were asked to choose the interview locations to make them feel as comfortable as possible throughout the interviews.

The interviewees were recruited in such a way that the greatest possible variance in demographic characteristics—gender, age, diabetes type, period since diagnosis, and form of therapy—could be covered [65,66]. The prerequisites for participation were the following: having an existing diabetic condition and being a Singaporean resident. Using such a broad cross-section of participants was undoubtedly a challenge, but only in this way was it possible for us to grasp the combination of different characteristics as widely as possible to gain insight into the use of mobile media in the diabetes context. Focusing on 1 or 2 characteristics (eg, only 1 diabetes type, 1 age group, or 1 type of treatment) would have restricted this view. Table 1 provides an overview of sample characteristics, and Table 2 provides additional information on participants. Moreover, it should be noted that 8 participants suffered from other diseases in addition to diabetes (eg, heart conditions, high blood pressure, high cholesterol, hypothyroidism, and/or breast cancer), 17 participants received diabetes education at some point, and 15 were part of a diabetes support group.

Both in the construction of the interview guide (see Multimedia Appendices 1 and 2) and in the analysis of the interviews, we followed a theory-driven approach, which differs from classic grounded theory or hermeneutics [67]. The interview guide was based on the MPA model and assessed the diabetes context, general daily diabetes self-management, and the use of Web-based (mobile) devices as part of diabetes self-care. It included 30 flexible questions, that is, if answers to a specific question had been provided before, the question was omitted.

All interviews were transcribed. The resulting transcripts each totaled 5000 to 10,000 words and were analyzed following a theory-driven approach on the basis of the research questions and the MPA model [41]. The data analysis followed a thematic-analysis approach as described by Braun and Clarke (2006), who define *thematic analysis* as "a method for identifying, analyzing, and reporting patterns (themes) within data" (p. 79), and it can be called "theoretical thematic analysis" because the themes are derived (at least partly) from the theoretical background, in contrast to an inductive approach [68]. The analysis was based on the categories' *functional*, *normative*, *symbolic*, and *restriction evaluations* as described in the MPA model, and it used the interview data to build themes around these theoretical concepts to identify commonalities and differences, as well as understand the appropriation of diabetes-specific apps for self-management in detail. If important interview extracts did not fit into existing categories on the basis of the MPA model, new subcategories were added. The procedure of creating categories and themes was dynamic and constantly adapted on the basis of the interview content. An institutional review board approval was received by NTU Singapore for the face-to-face interviews.

Study 2 Method

On the basis of the results obtained from study 1, study 2 asked for patterns of mHealth appropriation that can be found in the context of diabetes self-management. From June 2017 to August 2017, we conducted 16 semistructured interviews with German individuals with diabetes [64,65]. They were recruited through a purposive-sampling approach to cover a variance in the characteristics of age, diabetes type, period since diagnosis, and treatment [69-71]. We recruited interviewees via doctors in private practices and hospitals in Munich and Jena. Tables 3 and 4 provide more information about the sample.

The interview guide was based on our theoretical assumptions [41], study 1's results, and the interview guide developed for study 1. We adjusted it for language, as well as a broader understanding of mHealth use beyond specific diabetes apps. We asked the participants about (1) their smartphone use, (2) their knowledge about mobile media, (3) their attitude toward the use of mobile media in the context of diabetes, and (4) their self-management of their disease with the support of mobile media. The interview guide covered 21 questions.

Table 1. Singaporean sample characteristics (N=21).

Characteristic	n (%)
Gender	
Male	11 (52)
Female	10 (48)
Diabetes type	
Type 1	9 (43)
Type 2	11 (52)
Other (prediabetes)	1 (5)

Table 2. Singaporean sample.

Generic name[a]	Diabetes type	Age (years)	Gender	Years since diagnosis	Treatment
Kang	Prediabetes	67	Male	8	No medication
Adit	1	22	Male	10	Insulin (injection)
Cheng	1	23	Male	9	Insulin (injection)
Jie	1	64	Male	37	Insulin (injection) and Metformin or similar (oral)
Kaiyan	1	42	Female	36	Insulin (injection)
Navin	1	58	Male	38	Insulin (injection, pump)
Pang	1	19	Male	7	Insulin (injection)
Sona	1	20	Female	17	Insulin (injection)
Shi Hui	1	35	Female	28	Insulin (injection)
Xiu Wen	1	57	Male	32	Insulin (injection)
Bharat	2	66	Male	34	Insulin (injection)
Ching	2	64	Female	10	Metformin or similar (oral)
Deng Li	2	68	Female	4	Metformin or similar (oral)
Ei Tek	2	60	Male	31	Insulin (injection) and Metformin or similar (oral)
Gu Fang	2	29	Female	20	Insulin (injection, pump) and Metformin or similar (oral)
Henna	2	60	Female	24	Insulin (injection) and Metformin or similar (oral)
Li Ting	2	49	Female	9	Insulin (injection) and Metformin or similar (oral)
Ming	2	__b	Male	12	Metformin or similar (oral)
Rei Hong	2	61	Male	9	Metformin or similar (oral)
Xin Qi	2	56	Female	7	Metformin or similar (oral)
Zhen Wei	2	47	Female	18	Metformin or similar (oral)

[a]The transcripts were anonymized, and participants were given a generic name that matches with the in-text quotations.

[b]Age unknown.

The interviews lasted between 30 min and 60 min each, and they were audiotaped and transcribed into written form. The transcripts covered between 5000 and 10,200 words per interview. Our analysis was based on our paper's theoretical concept (MPA model) and study 1's results. We analyzed the interviews following the data-analysis process suggested by Creswell [71]. We read all transcripts, marked relevant passages, and abstracted them until we found the dimensions of mediated communication, diabetes self-management, and social prestige and control, ordering the presentation of the results. All responses were allocated to these 3 dimensions, and we identified similarities and differences among participants' usage patterns and linked study 2's results to the MPA model. The

Research Support Office of University Hospital Jena checked the interview guide and approved it. Information on sample characteristics can be found in Table 3, and the participants are described in Table 4.

Type 1 patients used the *Freestyle Libre* device by Abbot (n=5), Continuous Glucose Monitoring by Dexcom (n=2), or *Accu-Chek* by Avia with *Contour-App* (n=1) to test blood sugar levels. Only 1 patient relied only on test strips. Type 2 patients did not self-test blood sugar levels. Participants used IOS (n=6) or Android (n=10) devices. Only Andreas, aged 71 years and Linda, aged 42 years, used smartphones older than 5 years. In total, 9 participants used smartphones, which they had for less than 2 years.

Table 3. German sample characteristics (N=16).

Characteristic	n (%)
Gender	
Male	7 (44)
Female	9 (56)
Diabetes type	
Type 1	11 (69)
Type 2	4 (25)
Other (prediabetes)	1 (6)

Table 4. German sample.

Generic name	Diabetes type	Age (years)	Gender	Years since diagnosis	Treatment
Fiona	Prediabetes	29	Female	0	Unknown
Andreas	1	71	Male	18	Insulin (injection, pump)
Ben	1	64	Male	49	Insulin (injection, pump)
Conrad	1	31	Male	19	Insulin (injection)
Daniela	1	32	Female	22	Insulin (injection)
Emma	1	45	Female	30	Insulin (injection, pump)
Gerd	1	32	Male	20	Insulin (injection, pump)
Katja	1	43	Female	30	Insulin (injection)
Linda	1	42	Female	27	Insulin (injection, pump)
Olga	1	52	Female	35	Insulin (injection, pump)
Petra	1	25	Female	20	Insulin (injection)
Stefan	1	25	Male	9	Insulin (injection)
Jessica	2	56	Female	10	Metformin or similar (oral)
Marc	2	64	Male	0	Unknown
Norbert	2	58	Male	12	Insulin (injection, oral)
Ramona	2	43	Female	0	Metformin or similar (oral)

Results

Study 1 Results

Our first research question inquired about which specific functional, symbolic, normative, and restriction evaluations were relevant in the context of mHealth appropriation for diabetes self-management. Patients generally differed in their appropriation of apps designed for diabetes, with their use ranging from no previous use and no knowledge about existing diabetes self-management apps to infrequent and short-term app use as well as to long-term app use. The length of app use varied significantly, from a few days to several months or even years. Almost all type 1 diabetes patients reported using diabetes apps, whereas just a few type 2 patients used diabetes apps for their self-management. In addition, the interviews revealed that high-risk diabetic patients, that is, those with critical conditions or insufficient self-management, did not use diabetes apps (eg, Li Ting, aged 49 years; Ming, age unknown; Rei Hong, aged 61 years; Zhen Wei, aged 47 years).

Functional Use and Handling of Diabetes Apps

In terms of functional evaluations, the participants mainly mentioned diabetes monitoring and nutrition information. Diabetes monitoring almost exclusively referred to the use of blood glucose log books with a diary function to track blood sugar fluctuations (Dose Adjusting For Normal Eating app, *mySugr*, *Glooko*, Health Promotion Board *HPB* app, and *Diabetes M*). Nutrition information was related to the use of diabetes-database apps for gathering information about food content:

> *Another app I think will be useful is an app that is able to calculate for you the calories that you're going to be eating (...) So, I just have to enter [the food type] into the app and then it will work out for me how much carbohydrate.* [Kang, aged 67 years]

Diabetes Monitoring

For some, log-book apps replaced paper-and-pencil blood sugar logs by typing blood sugar results from the blood glucose meter into the app (eg, Bharat, aged 66 years; Cheng, aged 23 years;

Kaiyan, aged 42 years; Shi Hui, aged 35 years; Navin, aged 58 years). Some individuals with diabetes used log books that were automatically synchronized with glucose meters via Bluetooth (Henna, aged 60 years; Kaiyan, aged 42 years). The preference clearly leaned toward automated systems to facilitate glucose monitoring and avoided time-consuming monitoring processes (Sona, aged 20 years; Adit, aged 22 years). In addition, participants viewed log-book apps' automated data analysis to be useful, especially the improved sharing of blood sugar levels with health care professionals (Henna, aged 60 years; Shi Hui, aged 35 years). Some apps allowed data sharing with medical staff via clouds, whereas others used email (PDFs or Excel spreadsheets). However, cloud-based data sharing was linked to a minority of app users in the sample (Gu Fang, aged 29 years; Sona, aged 20 years), which can be partly explained by the fact that some participants expressed data-protection concerns. Xiu Wen, aged 57 years, explained in the following manner:

> If you put medical information in the cloud, then this becomes a...data-privacy issue.

Moreover, according to interview participants, Singaporean physicians were rather reluctant to recommend self-management diabetes apps that the government did not support—for a list of government-supported apps, please refer to the Singaporean Ministry of Health website [72]. Kang, aged 67 years, noted the following:

> Our doctors and staff...they have to be careful...If, for example, the doctor says, "Oh. Try this app." ...then if something goes wrong, they will publish it in the newspaper,...or they put it on Facebook. So, they don't try and say, "Oh, maybe you should try this app." ...They will never push it unless, if it's through the government.

Participants who reported using cloud services also used other mobile devices (such as step- and sleep-trackers, or glucose meters) and additional apps connected to diabetes apps (Henna, aged 60 years; Kaiyan, aged 42 years; Shi Hui, aged 35 years), thereby making broader use of their whole mobile-media ecosystem. Both type 1 and type 2 patients used log-book apps and reported their usefulness.

Nutrition Information

Mainly individuals with type 1 diabetes reported using food databases (Adit, aged 22 years; Cheng, aged 23 years; Pang, aged 19 years), likely because of type 1 patients' greater need for food-content information to accurately adjust their insulin with food intake. Cheng, aged 23 years, explained in the following manner:

> I roughly know my diet and my food, so I do the carb counting and stuff.

Pang, 19, said,

> The health-promotion board...I know they have an app for that [food database]; they also have it online so...whenever aaah...let's say I am unsure about how much carbohydrate a food has...(I) can always go look it up.

Detailed nutrition information was less relevant for type 2 patients who did not inject insulin. Apart from diabetes monitoring and nutrition information, the participants did not mention any further diabetes-specific app functions. Due to perceived limitations in diabetes-specific apps for self-management (see restriction evaluations), the participants used additional mobile devices and services for their daily self-management, including general health-information apps (eg, *WebMD*, *Health Buddy*), health and body mass index calculators, fitness apps (eg, *MyFitnessPal*), instant messengers (eg, *WhatsApp*), heart-rate monitors, and step- and sleep-trackers. Thus, on a more general level (not limited to diabetes apps), functional evaluations of health information and communication can be added to monitoring and nutrition information.

Symbolic Evaluations

Symbolic evaluations, which have been proven to play a role in the context of mobile phone appropriation in general, were not mentioned in the interviews.

Normative Evaluations

The influence of normative evaluations depends on patients' relationships with their doctors, and it is mainly seen with dependent patients who prefer to follow their physicians' instructions closely (Ei Tek, aged 60 years; Li Ting, aged 49 years; Ming, age unknown; Rei Hong, aged 61 years). Mostly, these patients did not use diabetes apps, and they were either skeptical of them or had no knowledge on how to use diabetes apps (Ei Tek, aged 60 years; Li Ting, aged 49 years; Ming, age unknown; Rei Hong, aged 61 years). These attitudes may reflect the prevailing sociocultural norms or perceptions of their personal physicians' views on apps.

Restriction Evaluations

Respondents often mentioned barriers to diabetes-app use and reasons for stopping app use. The reported evaluations mirror the 4 restriction categories, which the MPA model proposed: financial, temporal, cognitive, and technical. Financial barriers are mainly related to unwillingness to pay for diabetes apps. Shui Hui, aged 35 years, stated the following:

> Not all patients would be willing to pay.

Temporal restrictions are related to the time required to use app log books, for example, for monitoring blood sugar levels (Xiu Wen, aged 57 years). A lack of knowledge about app availability and use was reported as a cognitive barrier (Xiu Wen, aged 57 years). Technical barriers included technical failures, with some diabetes apps frequently *crashing* (Cheng, aged 23 years), resulting in a lack of reliability. In addition, 1 diabetes patient reported technical incompatibilities between diabetes apps and blood glucose meters (Gu Fang, aged 29 years). Overall, diabetes patients stressed that they did not perceive the apps to be a solution for diabetes-related challenges in general but rather as additional tools for patients with diabetes who generally are motivated and have enough knowledge about self-management:

> How motivated is the patient...somebody who's...very energetic,...it's interesting, you know, something that's new to them, they'll do it. [Xiu Wen, aged 57 years]

Meta-Communication

Our second research question inquired into what role meta-communication played in the appropriation of mHealth for diabetes self-management. Communication on the use of diabetes apps for self-management can be divided into communication with other diabetic patients or peers and communication with health care providers. Patients mentioned using Web-based chats, for example, *WhatsApp* (Cheng, aged 23 years; Ei Tek, aged 60 years), to discuss topics around diabetes management with other diabetic patients. Moreover, 1 diabetes patient participating in patient support groups mentioned chats as being relevant for information exchange and organization (Bharat, aged 66 years).

Meta-communication with health care providers played a relatively minor role. As mentioned, participants reported that their doctors *never* (Li Ting, aged 49 years) mentioned or recommended diabetes apps and rarely introduced new technological options to them (Ching Ching, aged 64 years), possibly being reluctant to recommend technology that the government has not tested and approved officially (Kang, aged 67 years).

Conclusions for Study 1

In summary, the interviews in Singapore revealed that evaluations of diabetes apps' usefulness for self-management differed largely in the sample and across patient types (eg, motivated vs unmotivated patients). Some participants found diabetes apps to be useful for daily self-management, used 1 diabetes app over a longer period, switched among different apps, or used various apps concurrently. Other participants did not perceive diabetes apps to be useful and stopped using them after the first trial or did not try apps for self-management at all. Although most participants tested or used diabetes apps, our results show that other mobile services and devices that are not necessarily diabetes-specific (eg, fitness trackers, dietary apps, and instant messaging) are used in addition to or instead of diabetes apps. Thus, study 1 indicates that Singaporean individuals with diabetes do not use diabetes apps exclusively but rather make use of the broader mobile-media ecosystem to manage their disease. Therefore, in the next study, we broadened our focus beyond specific diabetes apps to other tools in the mobile ecosystem.

Study 2 Results

We identified individual evaluations and, unlike study 1, further synthesized them into distinct appropriation patterns following the MPA model's [41] logic to answer our third research question. In total, 3 overarching dimensions of mHealth appropriation for diabetes self-management emerged: mediated communication comprising the functions of information gathering and social connectedness, diabetes self-management, including self-treatment, testing, and lifestyle management, and social prestige and control.

Mediated Communication

Diabetes patients, regardless of their diabetes type, used digital information to learn more about their disease, including *Google* (Linda, aged 42 years; Stefan, aged 25 years; Jessica, aged 56 years), *Wikipedia* (Marc, aged 64 years), or broad-spectrum websites to gather information about new diabetes developments (Ramona, aged 43 years; Marc, aged 64 years). Type 1 patients indicated gathering critical information on new technologies such as insulin pumps from corporate websites (Andreas, aged 71 years) or online forums (Emma, aged 45 years). Most of this information gathering was restricted to traditional forms of Electronic health (eHealth), mainly via the computer (Ramona, aged 43 years) and, to a lesser extent, via mobile devices. Younger participants used mobile devices (Petra, aged 25 years), whereas older patients or those with eye problems, regardless of diabetes type, complained about mobile devices' *small screen size* (Katja, aged 43 years), which can be interpreted as a technological restriction within mobile devices for people with varying physical conditions [73]:

> *You always have to put on your glasses on your mobile phone.* [Andreas, aged 71 years]

Gerd, aged 32 years, who followed a diabetic coaching list and self-help groups, mentioned *WhatsApp* as an additional information source beyond traditional Web-based searches (and not just as a communication tool).

With respect to social connectedness, other nonmediated forms of communication emerged as salient tools. Respondents talked face-to-face *to a neighbor* about diabetes (Norbert, aged 58 years) or with *my colleague's daughter* (Linda, aged 42 years), who also suffered from diabetes. These conversations continued on the Web, partly enabled by mobile devices. In general, the participants described a give-and-take approach to exchanging experiences, both asking for and providing information, for example, concerning technological developments. Some respondents also participated in discussions on the Web on costs, insurance, or specific self-management apps (Conrad, aged 31 years; Fiona, aged 29 years; Olga, aged 52 years). Others were more critical and described some forums as *hysterical*, highlighting that information gathered there needed to be put into perspective by their physicians. Jessica, aged 56 years, stated the following:

> *Often, there is a discussion in the forum, then a doctor intervenes and writes, "So, I am a doctor, and I can now say this and that." And then he corrects some things when someone has written something totally bad.*

WhatsApp played an important role, with participants taking part in certain thematic, for example, food-focused, groups (Jessica, aged 56 years; Ben, aged 64 years). Gerd, aged 32 years, described an interesting case of social connectedness and exchange in mHealth by posting his blood glucose levels on the Web for his remote diabetes counselor to access. When far apart, the counselor used *WhatsApp* to contact Gerd immediately if some values were out of bounds. Nevertheless, such instrumental use of social media apps was a rare occurrence in the interviews as most patients only used such apps to exchange information with peers or other patients and not to expand doctor-patient communication.

Moreover, 1 restriction observed in the use of mediated communication for social connectedness and exchange, both mobile and static, was that information on the internet was not always considered trustworthy (Daniela, aged 32 years). On a

more symbolic dimension, those in need of exchange were deemed incapable of self-management, or as Daniela, aged 32 years, stated, *wimpy*.

Diabetes Self-Management

For diabetes self-management, we saw a rather clear-cut distinction between type 1 and type 2 patients—a pattern also seen in study 1's results with respect to app use. Although self-treatment and self-testing were more relevant for type 1 patients, lifestyle was a relevant subdimension for patients of both types.

Self-treatment and self-testing mostly related to the use of smartphones for measuring and tracking blood glucose levels and/or for using diabetes-management apps, such as *My Sugar*. For diabetes self-management, the *Freestyle Libre* app played a crucial role, giving type 1 patients more control and autonomy on a symbolic level. Stefan, aged 25 years, thinks these apps are *cool*. However, we also observed several restrictions. Even though devices like *Freestyle Libre* and their connectivity with smartphones gave users more autonomy, they traded this freedom for a reliance on their smartphones:

> *I am depending on battery life.* [Fiona, aged 29 years; Gerd, aged 32 years]

IOS (Apple operating system) users like Petra, aged 25 years, could not use the *Freestyle Libre* app as it was incompatible with IOS (at the time of the study). Linda, aged 42 years, who used 1 of the oldest phones in the sample, simply could not use any measurement apps, as her phone did not support them. Olga, aged 52 years, used a Continuous Glucose Monitoring (CGM) sensor and the *Stealwise App* on a Sony Z5. She mentioned financial constraints as *health costs a lot of money*. Ben, aged 64 years, using a new iPhone and CGM sensors, stated the following:

> *If I cannot use the device, it goes along with not being able to use the app.*

As previously noted, the use of smartphones as platforms for self-testing apps has limited functionality, as smartphone screens are difficult to read, especially for diabetes patients with eye diseases (Andreas, aged 71 years; Katja, aged 43 years). Furthermore, all users, regardless of technological (or financial) restrictions, considered the lack of connectivity among different devices—smartphones, insulin pumps, and sensors—to be problematic (Conrad, aged 31 years; Emma, aged 45 years):

> *Every device does its own things.* [Andreas, aged 71 years]

To overcome this issue, Gerd, aged 32 years, who had a background in computer programming, even tried to create or at least adjust his own apps for better connectivity. Overall, we saw widespread use of mobile devices for self-testing, with some connected to participants' smartphones, whereas others were not. This gave patients more autonomy in their lifestyle and health management, but technology reliability remained suboptimal, particularly with missing connectivity, low usability, and an even stronger reliance on smartphones, which were already used for a plethora of other everyday life activities.

The use of mobile devices, such as smartphones or fitness trackers, for lifestyle management is another aspect that we identified as a relevant use dimension. We observed 3 rather distinct appropriation styles, including nonusers who either considered the tracking of lifestyle information (eg, steps, calorie intake, and weight) to be more or less useless (Petra, aged 25 years; Ramona, aged 43 years) or used tracking, particularly step tracking, with an app (Daniela, aged 32 years) or a fitness tracker (Olga, aged 52 years; Marc, aged 64 years) but had ceased this usage. For others, such technology was a source of inspiration to become more active. Gerd, aged 32 years, used the location-based game *Ingress* to get more active. Ben, aged 64 years, was proud of his *AppleWatch* and its functionalities, an important symbolic aspect, and Emma, aged 45 years, integrated the *Polar App* and *Watch* into her daily routines. Lifestyle management with mobile devices was carried out by some of our participants mainly by focusing on step counters through apps, fitness trackers, or smartwatches. Nonetheless, a discrepancy existed between patients' needs and app availability. Patients, particularly those with type 2 diabetes, saw great potential for apps to help with their eating habits (Emma, aged 45 years; Jessica, aged 56 years). Katja, aged 43 years, wanted to use a nutrition app but had not found any suitable choices. These diabetic patients were looking for an app to track their everyday life behaviors and compute the required insulin doses accordingly, thereby allowing them to act spontaneously and freely in their everyday lives.

Social Prestige and Control

The use of mobile devices and/or apps, particularly for testing, gave technologically savvy (type 1) patients a sense of agency. This was accompanied by an increase in social prestige, as they became experts not only with respect to their own disease but also with respect to new technologies (Fiona, aged 29 years; Gerd, aged 32 years; Olga, aged 52 years). First, meta-communication about diabetes and diabetes management comes into play as other patients recommended these technologically savvy individuals with diabetes to test technology or asked them about testing results. For example, Gerd, aged 32 years, a software programmer, was proud of his self-programming of apps to solve existing problems and fulfill other diabetic patients' needs. Second, besides enhanced agency and the claim of being a pioneer, social prestige was enriched from a device perspective. For example, in the words of Ben, aged 64 years:

> *There is a kind of luxury [owning the newest devices].*

In this way, Ben points to the issue of social status *vis-a-vis* appropriation.

Discussion

Principal Findings

Our objective was to provide a more comprehensive view of mHealth use for diabetes self-management beyond the simple question of adoption versus rejection. Study 1, conducted in Singapore, specifically aimed to identify evaluations of diabetes-app use and appropriation for self-management. Most importantly, study 1 revealed that diabetes patients do not

merely use specific diabetes apps for their daily diabetes self-management but rather make use of their whole mobile-media ecosystem, such as other health apps, chat apps, or Web-based databases. Building on these findings, we broadened our perspective in study 2, conducted in Germany, more generally examining not only diabetes-app use but also mobile-media use in diabetes self-management, including information search and retrieval, and monitoring linked to diabetes self-management.

The semistructured interviews revealed several functional, normative, and restriction evaluations that play a role in both studies, whereas symbolic evaluations only appeared in study 2. In particular, the following functional, symbolic, normative, and restriction evaluations were identified (RQ1):

1. Functional evaluations mainly refer to the use of diabetes apps for diabetes monitoring, such as log-book apps used for recording and sharing results with health care providers and the use of diabetes apps for nutrition information. However, patients also mentioned using alternative mobile apps and channels for their daily diabetes self-management, namely apps for general health information (eg, fitness apps, *WebMD*), as well as apps to communicate with other patients (eg, *WhatsApp*).

2. Symbolic evaluations were not observed among Singaporean patients but appeared to play a role in the German study. The use of mobile devices and apps gave patients a feeling of agency and a boost in social prestige through owning a new device or through instilling a sense of being technological pioneers. However, Singaporean diabetes patients did not mention any of these aspects, which might be explained by sociocultural differences between the 2 countries: German society is conceived as more individualistic than collectivistic Asian societies [74]. Thus, using mHealth for diabetes self-management as a vehicle to demonstrate technical knowledge and social status might only play a role in more individualistic cultures.

3. In terms of normative evaluations, we found that patients' relationship with their doctors plays a major role. This observation is linked to a second cultural difference in our 2 studies. Singaporean patients who were highly dependent on their doctors' recommendations were hesitant to use diabetes apps, as their doctors did not actively advise using them, as they seemed reluctant to recommend apps that the Singaporean government had not sanctioned. In the context of sociocultural barriers proposed by the information communication technologies for health care model [60,61], the collectivist nature of the Singapore society is premised on Confucian principles [74] that might play a role here. As extant studies show, further reasons for doctors' reluctance, including in Germany, could be a lack of perceived usefulness, technical concerns, and familiarity and privacy issues [75,76].

4. Finally, diabetes patients indicated several restriction evaluations, namely financial, temporal, cognitive, and technological barriers to diabetes-app use. Regarding technological barriers, diabetes patients complained about their smartphones' small screen sizes, dependence on battery life, and apps' incompatibility with older smartphones, other devices such as insulin pumps, and other patients' needs.

As proposed by the MPA model in the context of mobile phone appropriation, meta-communication also plays a role in diabetes self-management with diabetes apps (RQ2). Interestingly, diabetes patients discuss topics around diabetes management mainly with other diabetes patients, in online diabetes support groups or via *WhatsApp*. In contrast, physicians only play a minor role, as they are reluctant to recommend or mention diabetes apps.

Regarding RQ3, study 2 revealed 3 overarching appropriation patterns emphasizing that the use and everyday-life integration of mHealth in diabetes self-management are not restricted to simple diabetes-app use:

1. The *mediated communication* pattern embraces information gathering about diabetes, including therapies and medication, using traditional forms of eHealth via computers and mobile devices, as well as connectedness and exchanges with peers and other diabetes patients face-to-face via chat functions or online support groups. Restrictions in this pattern mainly refer to mobile phones' small screen sizes and a lack of trustworthy information on the Web.

2. The *diabetes self-management* pattern includes self-treatment and monitoring, as well as lifestyle-management. This pattern mirrors what is typically described as the use of mHealth for diabetes self-management, namely the use of smartphones to measure and track blood glucose levels and the use of self-management apps. In this context, the interviews revealed important restrictions, such as a feeling of dependence on smartphones (eg, battery life), compatibility issues tied to different devices and app versions, screen size (especially for patients with eye diseases), and costs. In addition, support on adequate nutrition and physical activity appeared to be a further dimension. However, in this context, use patterns are very diverse, and several patients stopped using such apps after a while, possibly because of discrepancies between patients' needs and apps' functionalities, as patients would prefer a one-size-fits-all app that fulfills all their needs.

3. The *social prestige and control* pattern refers to the symbolic aspect of mHealth use for diabetes. It mostly develops with experienced app use as it gives patients a feeling of empowerment regarding both their own disease situations and the use of new technologies. With more expensive devices, social prestige also comes into play. In this pattern, meta-communication plays a specific role, as experienced patients can serve as opinion leaders to support other less-experienced patients.

Thus, studies 1 and 2 complement each other in 3 aspects:

1. We expanded our research focus by focusing not only on specific diabetes apps (study 1) but also on the use of smartphones within the whole mobile-media ecosystem (study 2). In this paper, we see that mHealth and eHealth apps go hand in hand with mHealth, expanding traditional forms of eHealth, such as using the internet for

information-gathering and (social) exchange. *WhatsApp*, as a mobile-specific communication app, plays an important role, as it helps connect patients with each other and acts as both an information source and a communication tool for fellow patients, friends, family, and, to a lesser extent, doctors. However, as already demonstrated in study 1, doctor-patient communication about diabetes apps, as well as meta-communication in general, is limited. Therefore, we reiterate earlier calls [18] for greater integration of technological innovation within the overall health care system rather than perceive them as stand-alone entities.

2. This expansion in our focus highlighted that differences between type 1 and type 2 patients were not limited to diabetes-app use but included the entire appropriation process of mobile technologies for diabetes self-management. It appears that type 1 patients, potentially because of their greater need to manage diabetes, were more technologically savvy. In addition, acquiring digital skills to use such technology became an important aspect for gaining control over their lives, as well as respect from fellow patients, friends, and colleagues. In this context, it should be noted that to gain a broad picture of mHealth appropriation in the diabetes context, we included both type 1 and type 2 diabetes patients in our studies, with the results indicating both commonalities and differences between these 2 patient groups. Among type 1 diabetic patients, mHealth use was more generally common; they also used food databases more often, probably because of these patients having a greater need to monitor food ingredients. This pattern evolved both in studies 1 and 2, indicating that self-treatment and self-testing (eg, blood glucose levels) were more relevant to type 1 patients, giving them more control and autonomy, whereas lifestyle management was relevant to both types. Apart from that, use and appropriation patterns with various mobile devices and apps were rather similar in both patient groups. As this study did not focus on detecting differences between type 1 and type 2 diabetes patients, future studies should examine the potential differences further.

3. We looked at diabetes self-management in 2 different health systems, that is, Singapore and Germany. Although we did not primarily intend to compare mHealth use in different health systems or countries, looking at 2 distinct contexts allowed us to look for similarities and differences: functional, normative, and restriction evaluations were very similar between Singapore and Germany, although sociocultural differences emerged. Regarding restriction evaluations, we noted monetary and technological restrictions as recurring patterns in both studies. Regardless of the health system, monetary costs played a crucial role, which were particularly relevant for type 1 patients. Furthermore, patients needed devices to be compatible with each other. In addition, we found, in both cases, that even older patients with diabetes were interested, at least partially, in new technology and successfully employed strategies to integrate mHealth devices and smartphone apps into their diabetes self-management.

Limitations

Further research also is needed to address a few limitations. First, we conducted the 2 studies in 2 different countries despite the fact that we did not intend to compare appropriation processes. On the contrary, it was our objective to extend research that we conducted in Singapore both to a broader perspective on mHealth appropriation and to another country to assess recurring patterns in 2 different cases. The 2 countries are comparable regarding the relevance of diabetes, industrialization, smartphone penetration, and the presence of a well-developed health system. However, cultural differences must be acknowledged. This might explain why we did not find symbolic evaluations in Singapore, whereas in Germany, social prestige evolved as a relevant aspect of mHealth appropriation. It also should be noted that even if both countries rank among the top nations regarding technological development, it remains unclear how widely attitudes toward technology differ in Singapore versus Germany. Our results did not reveal any major differences regarding smartphone use for diabetes self-management; nevertheless, future research should consider this aspect in more detail. In addition, we did not systematically control for the influence of socioeconomic status and thus cannot make any statements on this. Finally, because of rather small sample sizes, qualitative research generally lacks generalizability in the results. However, a qualitative approach was a necessary step to gain deeper insights into diabetes patients' appropriation patterns and everyday lives and to identify evaluations relevant to them [77]. In the next stage of research, our findings can be used to develop standardized questionnaires to gain insights into the distribution of appropriation patterns among a broader population.

Conclusions

The study of mHealth apps for diabetes management is in a nascent stage with not only promising results but also many open questions [12-19]. In this project, studies 1 and 2 revealed that appropriation of mHealth for diabetes self-management is not limited to using specific diabetes apps but rather includes patients' entire mobile-media ecosystem. Even if diabetes apps play a role, especially for self-treatment and self-testing, diabetes patients use many more digital resources when dealing with their conditions, such as lifestyle apps, messenger apps, traditional health-information websites, or forums accessed from a computer or mobile device. Thus, mHealth is important for diabetes self-management but in multiple ways that go far beyond diabetes-app use. In addition, our findings indicate that mHealth cannot substitute for interpersonal communication, for example, with other patients, peers, or health care providers, but it complements and supports interpersonal communication, especially via messenger apps. However, doctor-patient communication only plays a minor role in this context and can even be a barrier to mHealth use, as doctors are reluctant to recommend using mobile apps. Further reasons for diabetes patients to be reluctant to use mHealth for diabetes (continuously) include financial, technical, cognitive, and temporal issues. Apart from individual constraints (eg, eye problems, technical skills, and use of outdated devices), it appears that patients still cannot find what they are looking for. Patients want a not-yet-existent app that combines everyday-life

requirements while computing correct insulin doses, thereby allowing for more freedom and spontaneity. Thus, considering these recurring evaluations, the appropriation of mHealth for diabetes self-management could be enhanced if doctors were less reluctant to recommend self-management apps, if connectivity between devices and apps, including multipurpose apps, was improved, if apps adapted to users' physical restrictions (eg, font size), and if people already using mobile media for diabetes self-management were integrated into new apps' development process and used as consultable opinion leaders to facilitate appropriation for others.

However, even if some overarching issues evolve, not every app solution can accommodate each and every patient. This is reflected in the 3 overarching dimensions of mHealth appropriation for diabetes self-management that we uncovered: (1) mediated communication (information-gathering, connectedness, exchange), (2) diabetes self-management in a narrow sense (self-treatment and monitoring, lifestyle-management), and (3) social prestige and control (symbolic aspects of mHealth use for diabetes). Diabetes patients differ highly in respect to these dimensions, that is, *how* they use mHealth for diabetes self-management, for *what purposes* they use it, and how they *evaluate* use. Integrating this knowledge into future mHealth apps' designs and effect studies might shed more light on mHealth's great potential for diabetes self-management.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Interview guide (Singapore).

[PDF File (Adobe PDF File), 51KB - diabetes_v4i1e10271_app1.pdf]

Multimedia Appendix 2

Interview guide (Germany), translated into English.

[PDF File (Adobe PDF File), 42KB - diabetes_v4i1e10271_app2.pdf]

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Abbreviations

CGM: Continuous Glucose Monitoring
eHealth: electronic health
mHealth: mobile health
MPA model: Mobile Phone Appropriation model
RQ: research question
TAM: Technology Acceptance Model
UTAUT: Unified Theory of Acceptance and Use of Technology

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Original Paper

Impact of New Technologies for Middle-Aged and Older Patients: In-Depth Interviews With Type 2 Diabetes Patients Using Continuous Glucose Monitoring

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Abstract

Background: Continuous glucose monitoring (CGM) uses subcutaneous sensors and records the average interstitial sensor current every 5 min in the recorder; data are subsequently exported to a computer 4 to 7 days later when calibration with self-measured blood glucose is made retrospectively. How middle-aged and older patients perceive the added technology intervention is not clear.

Objective: The study aimed to understand the factors associated with the adoption of new technology in diabetes care, to understand the feelings and behaviors while using it, and to determine the changes in attitudes and behavior after completing the use of the new technology at the 3-month follow-up.

Methods: Middle-aged and older type 2 diabetes patients who had received professional continuous glucose monitoring (iPro 2 [Medtronic]) were invited for semistructured in-depth interviews on the day of the CGM sensor removal and at 3 months after CGM-based counseling. A phenomenography approach was used to analyze the interview data.

Results: A total of 20 type 2 diabetes patients (aged 53 to 72 years, 13 males and 7 females, 4 to 40 years duration of diabetes, mean glycated hemoglobin 8.54% [SD 0.71%]) completed 2 sections of semistructured in-depth interviews. Physician guidance and participant motivation toward problem solving were found to be factors associated with adoption of the device. Participants indicated that technology can be a reminder, a supervisor, and a visualizer of blood glucose, all of which are helpful for disease management. However, CGM is somewhat inconvenient, and some participants also reported that the provision of this new technology might be a hint of disease progression. There was a higher percentage of women compared with men who reported that CGM can be a reminder or a supervisor to help them with diet control.

Conclusions: Physician guidance and participants' degree of motivation are keys to adopting new technology in the case of middle-aged and older adults. Although the CGM sensor may cause inconvenience to patients on their limited body movement when wearing the device, it is helpful for diet control and is an effective behavioral modification tool that offers support, especially in the case of women.

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Introduction

Background

Type 2 diabetes is a highly prevalent disease that increases in frequency with age. In Taiwan, diabetes ranks fifth [1] among the top 10 leading causes of death, and the prevalence of diagnosed type 2 diabetes is over 20% of the population over the age of 60 years [2]. In the future, the proportion of type 2 diabetes will continue to rise as the elderly population increases. In Taiwan, care and management practices for type 2 diabetes are basically consistent with the standards set by the American Diabetes Association, which emphasizes the importance of blood glucose management and blood glucose monitoring [3]. Maintaining normal blood glucose levels can prevent damage to the retina, kidneys, and other organs [4]. It has also been suggested in the past that a 1% reduction in glycated hemoglobin (HbA_{1c}) can reduce other complications by 14% to 37% [5].

Control of blood glucose is assisted through self-monitoring of blood glucose levels. Generally, blood glucose measurement with a glucose meter allows patients to determine their current blood glucose levels. However, even 7-point self-measured blood glucose (SMBG) levels fail to accurately display the whole picture of blood glucose fluctuations that occur in a diabetic patient during the day. Professional continuous glucose monitoring (CGM) uses subcutaneous sensors and records the average interstitial sensor current every 5 min in the recorder; the data are subsequently exported to a computer 4 to 7 days later when calibration with SMBG is made retrospectively. The recorded results can display continuous fluctuations in blood glucose levels during the days when the patient carries the sensor. The patient must also record the blood glucose level 4 times a day for calibration of the blood glucose level. At the same time, the patient is requested to maintain a personal diet diary and record leisure activities so that the diabetologist can identify the reason for unexpected blood glucose fluctuation, which may result in suggestion of diet adjustment or antidiabetic drug adjustment. So far, professional CGM has been clinically used for patients with diabetes. Despite lack of strong evidence favoring professional CGM over SMBG in improving glycemic control, it is assumed that professional CGM is a tool for communication between physicians and patients to modify the treatment strategy [6].

In previous studies, real-time continuous glucose monitoring (RT-CGM) has been compared with SMBG and internet blood glucose monitoring (IBGM). There has been no significant difference between RT-CGM and IBGM in terms of their effects on HbA_{1c}, and both have been shown to be better than SMBG alone [7,8]. However, although RT-CGM may provide better monitoring, subjects noted that wearing the CGM sensor is more likely to make them uncomfortable because it may cause conditions, including skin irritation and sleep disruptions, owing to the system alarm and thus may even cause subjects to become dissatisfied or prematurely end or refuse the use of RT-CGM [8]. In addition, previous studies on patients with type 1 diabetes have also suggested that other social factors may also be associated with the experience of using this monitoring system. First, the inconvenience of the monitoring system is a problem that must be solved. Patients who like the system find this problem to be tolerable. However, patients who do not like the system are heavily affected psychologically by its use and tend to have a poor user experience. Second, regarding the use of information, patients who are positive about the system suggest that this system may help increase their understanding and self-management of their glycemic status. However, patients who do not like the system think that too much information may not be relevant. Finally, care and encouragement from family and friends in the form of social support have a positive effect on the use of the CGM system as well as participant acceptance of the system. RT-CGM can also reduce the family's anxiety about the disease, such as concern about hypoglycemia, and thus can improve the quality of life of patients [9]. In addition, when patients are more concerned about the control of blood glucose levels, they are not only willing to spend more time trying out this new technology but are also more willing to tolerate some of the discomfort caused by the system, such as skin allergy and irritations and alarm sounds [10].

Objectives

Despite current research on the CGM system, most studies are conducted among patients with type 1 diabetes [9-12] using RT-CGM but not professional CGM [7-9,11]. In addition, current research on the CGM sensor has mostly focused on European countries and the United States [7-12]. At present, application of professional CGM among patients with type 2 diabetes in Taiwan is limited in the research field owing to its high cost that is not covered by the National Health Insurance (NHI) [13-15]. As a tool to aid in the management of type 1 diabetes [16], patients with type 1 diabetes can use the insulin pump along with RT-CGM to monitor their blood glucose levels, to reduce hypoglycemia, and to reduce insulin dosage [17] or to monitor preterm infants delivered by women affected by diabetes [18]. From the literature review, the perception of professional CGM among middle-aged and elderly patients with type 2 diabetes in non-Western countries is still lacking. Middle-aged and elderly people are very different from children or young adults in many aspects. They have different daily activities, social networks, and family support systems. Therefore, an exploration of the short-term and long-term acceptability of new technologies and whether they will bring about positive changes in behavior is urgently needed. Professional CGM (iPro 2) is the only available CGM device in Taiwan. We performed in-depth interviews to explore the acceptability and experience of professional CGM among middle-aged and older individuals and to explore the impact of professional CGM-based counseling on their health literacy and lifestyle.

Methods

Participant Selection

We recruited middle-aged and elderly patients with type 2 diabetes at an endocrinology outpatient department in a medical center in southern Taiwan. The inclusion criteria were as follows: patients with type 2 diabetes who were 45 years or older with inadequate controlled blood glucose (at least 2 of the last 3 HbA_{1c} readings at 7% or more) and patients who were

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suggested professional CGM as an interventional tool to improve their glycemic control by their primary care physician. Participants were excluded if they reported being diagnosed with generalized inflammation; advanced malignancy; end-stage renal disease on regular dialysis; status post renal transplantation; end-stage liver, heart, or pulmonary disease; or had any acute or chronic inflammatory disease as determined by a leukocyte count over $10,000/mm^3$ or clinical signs of infection. Patients diagnosed with thalassemia, glucose-6-phosphate dehydrogenase deficiency, or any other hemoglobinopathies that could influence the accuracy of the HbA_{1c} measurement were also excluded. In addition, patients who had HbA_{1c} levels above 12% at a recent outpatient visit were excluded owing to limitations of the CGM device to calibrate blood glucose above 400 mg/dL. Finally, participants who could not follow orders because of cognitive impairment or who were bedridden were also excluded. All participants provided written informed consent before the trial, and they also received compensation for their time. As for sample representation, the participants in our study were not limited to certain gender, occupation, educational level, duration of diabetes, or age. We tried to collect more information from participants in variable backgrounds. Besides, data collection continued until it was believed that data saturation had been achieved. The point of saturation was determined when new added data from participants no longer changed the researchers' understanding about the topic.

Continuous Glucose Monitoring Procedure

Participants wore professional CGM (iPro 2) for 5 days and measured their blood glucose at least 3 times a day for calibration of interstitial glucose readings. Participants were also requested to complete a diet diary with a photo record every day. After 5 days of wear, the sensor was removed. A semistructured in-depth interview for opinions about CGM and feelings during CGM was conducted on the day of the CGM sensor removal. The primary care physicians used CGM as a counseling tool to motivate patients to adjust their diet and exercise habit and to also make decisions on drug adjustment, if necessary, at the prescheduled outpatient visit. The second interview collected opinions about satisfaction of CGM and its influence on family members at the 3-month follow-up.

Data Collection

A total of 2 semistructured in-depth interviews were conducted to collect information about the participants' feelings and experiences related to CGM device usage. For the first interview, opinions about CGM and feelings when wearing the CGM device were explored on the day of the CGM sensor removal. For the second interview conducted at the 3-month follow-up when they visited the outpatient clinic, we focused on participant satisfaction with the device. All interviews were conducted by 2 trained researchers. We asked broad, open-ended questions about their opinions on the CGM device and adjusted the questions and asked for more details according to the flow of the conversation. Both the interviews were conducted for 15 to

20 min in a private room where participants received health education. We conducted the interviews at a familiar place to avoid effects due to unfamiliarity with the location of the interviews. All interviews were audio-recorded and transcribed verbatim. We analyzed the verbatim answers reported by the participants and categorized them into different concepts. The participants' names and identifiers were removed to protect their confidentiality.

Data Analysis

According to Dahlgren and Fallsberg's recommendations [19], we listened to the interview content again to familiarize ourselves with the content and then transcribed it verbatim. We performed an analysis by labeling the content related to the structured discussion guide and comparing the content between different participants. Then, we categorized key words, phrases, and texts to determine the themes. We divided the participants' answers into 3 topics: (1) participants' adoption of the CGM device, (2) behavior while wearing the CGM device, and (3) can CGM be an effective behavioral modification tool? Finally, we concluded the core concept of each category and coded related quotes to explore the participants' actual interaction with this new diabetes technology.

Ethical Considerations

This study was approved by the Institutional Review Board of National Cheng Kung University Hospital on January 21, 2016 (IRB #B-ER-104-239).

Results

Overview

A total of 20 participants (13 males and 17 females) were recruited in this qualitative study. Figure 1 illustrates the details of the enrollment flow. Initially, all of the 20 participants signed informed consent forms and participated in the first part of the interview, which is about the opinions and feelings about CGM during 5 days of professional CGM exam. Among them, 17 participants completed the second part of the interview, which is about the satisfaction of CGM and influence of CGM on themselves and their family members.

As shown in Table 1, mean age of the 20 participants was 61 (SD 5) years, with the long-standing diabetes duration being 16 (SD 8) years, and body mass index 27.98 (SD 3.42) kg/m^2. Before CGM, the mean HbA_{1c} among these participants was 8.54% (SD 0.71%), and the mean fasting blood glucose level was 177 (SD 48) mg/dl (Table 1).

There were 3 main areas that were explored in this study: (1) why they agreed to adopt the CGM device in their diabetes treatment, (2) their feelings related to incorporating technology into regular disease management behavior, and (3) by obtaining the attitude or behavioral changes before and after the CGM intervention, we tried to determine whether CGM is an effective behavior modification tool. Several themes for each question were identified (Table 2).

Figure 1. Enrollment flow diagram. CMG: continuous glucose monitoring; SMBG: self-measured blood glucose; 3m: 3 month; 6m: 6 month.
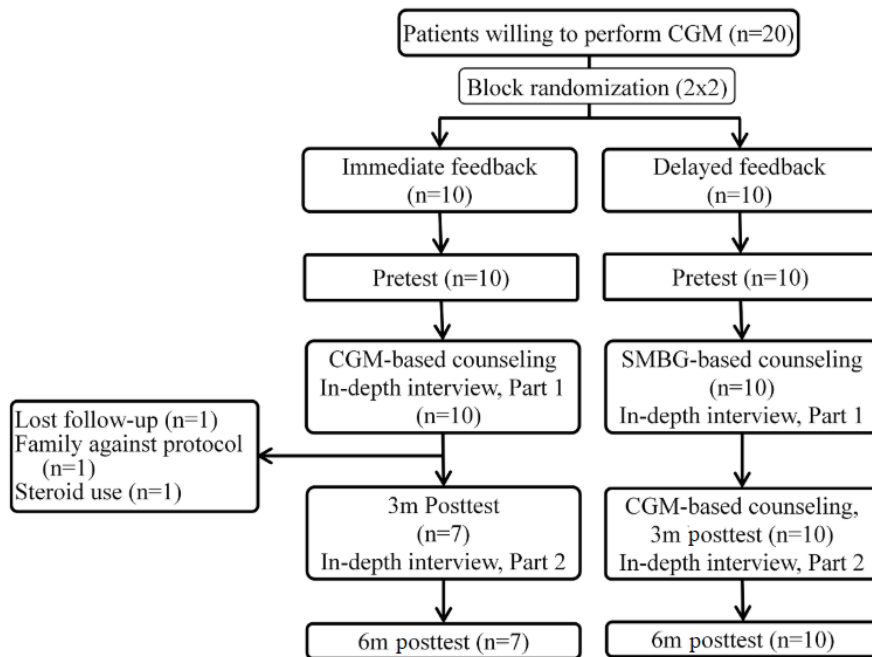
Factors Related to Participants' Adoption of the Continuous Glucose Monitoring Device

For this question, we explored the participants' adoption of the device. We asked them about their motivation to participate in the trial and asked what factors affected their decision. In addition, we explored their initial perceptions of the device. According to their answers to each question, we categorized their responses into 2 themes as follows:

Theme 1: The Physician as an Authority Was Effective and Determinant

With regard to the participants' adoption of the CGM device, professional authorities played an indispensable role. For the participants, the doctor assumed the role of a professional authority who was an information provider. Most of the participants had never heard of the device until doctors told them about it. The participants learned more about CGM from doctors or health education providers. At the same time, it increased participants' motivation to receive the trial:

> *I participated because the doctor told me that it would be better to know what my blood glucose level was. My glycated hemoglobin was 7 [%] or so, but my [fasting] blood sugar level was 190 [mg/dl]. He said it was disproportionate, so I needed to wear this to know my blood glucose level.* [No. 08, age 65, female]

> *The doctor told me that it would help me understand the changes in my blood sugar level and how it functions... It could effectively monitor changes in my blood sugar level because in the past, we only measured blood sugar levels in the morning or after meals. So, to understand the real changes to my body condition, it would be more effective this way. My blood sugar levels were suddenly high and low, and I did not know whether the cause of the problem was something I ate or other bodily conditions. If I go*

> *through this, it should help me in some way. So, I gladly agreed.* [No. 05, age 61, male]

In addition, professional authorization was one of the important motivations that led participants to participate in the trial. Owing to their trust in a professional authority, participants were willing to give it a try:

> *I thought the doctor's advice would be helpful. So, I said yes!...Owing to the physician's enthusiasm, I felt that he was enthusiastic about helping me control my blood sugar levels and improve my body condition, and I did not want to lose the physician's good will.* [No. 06, age 56, female]

However, professional authorities might have forced patients to participate in the trial. Of all the participants, 1 was afraid of rejecting the doctor's recommendation because he felt that if he did not participate, the doctor would not provide him with medical care anymore.

Under these circumstances, he decided to participate in the trial:

> *There is not a specific reason. I am doing it because the physician suggested that I do this...We are not doctors, and how can we know? We just do whatever the doctor tells us to do.* [No. 17, age 55, male]

> *I dare not tell him I don't want to! I cannot say it! I am afraid that the doctor will refuse my appointments in the future.* [No. 03, age 62, male]

Theme 2: Motivation to Solve Problems as a Key to Adoption

Besides professional authorization, most of the reasons for participation in the trial included the participants' desire to understand their physical condition better. The participants looked forward to figuring out better treatment plans:

All I can answer is that I am doing this [experiment] for my own good! And I also want to know where the problem lies! [No. 08, age 65, female]

Feelings of Incorporating Technology Into Regular Disease Management Behavior

In this section, we explore the participants' perceptions of CGM. We asked participants about their daily life while wearing the device and the role that it played. Did participants change their daily life, such as exercise and dietary habits, because of CGM? How did it affect their daily life? According to the participants' answers to each question, we categorized them into 5 themes as follows:

Theme 1: Technology as a Reminder

In addition to participant perceptions, CGM also affected their behavior. For instance, it could serve as a reminder. Participants had to measure blood glucose 4 times every day. When they saw the blood glucose results, it reminded them about things such as changing their food intake, and the results also reminded them what they had eaten earlier in the day:

Well, if my blood sugar level is high, I will try to recall what I have eaten to make my blood sugar level so high, and then I would control my diet. For example, I would buy a baked scallion pancake that I really wanted to eat, but I would not eat it all at once. I would only take one bite or two, and I would wait for 1 or 2 hours to have another bite. It is like payment in installments. Ha! [No. 09, age 64, female]

Table 1. Sample demographics (n=20).

Population demographic characteristic	Statistics	Range
Age (years), mean (SD)	61 (5)	53-72
Duration of diabetes (years), mean (SD)	16 (8)	4-40
Gender, n (%)		
Male	13 (65)	—[a]
Female	7 (35)	—
Education, n (%)		
Elementary graduate	5 (25)	—
High school graduate	10 (50)	—
College education or greater	5 (25)	—
Body mass index (kg/m^2), mean (SD)	27.98 (3.42)	22.40-34.37
Glycated hemoglobin (%), mean (SD)	8.54 (0.71)	7.3-10.0
Fasting blood glucose (mg/dl), mean (SD)	177 (48)	—
Blood pressure (mm-Hg), mean (SD)		
Systolic pressure	138 (19)	110-203
Diastolic pressure	84 (12)	60-115
Physical activity, n (%)		
No	4 (20)	—
1-2 times every week	5 (25)	—
3-4 times every week	4 (20)	—
>5 times every week	7 (35)	—
Smoking, n (%)		
Yes	2 (10)	—
No	18 (90)	—
Drinking, n (%)		
No	17 (85)	—
Occasionally	2 (10)	—
Often	1 (5)	—

[a]Not applicable.

Table 2. Themes and answers to questions.

Themes	Participants' adoption of CGM[a]	Perception of CGM	Can CGM be an effective behavior modification tool?
Theme 1	Physician's advice was an effective determinant: "The doctor told me that it could help me understand the changes in my blood sugar level, and it functions in that way... It could effectively monitor changes in my blood sugar level; I asked many people, and they did not know much about this. We are not doctors, so how can we know this? We do whatever the doctor tells us to do"	Technology as a reminder: "Well, if my blood sugar level is high, I will try to recall what I have eaten to make my blood sugar level so high, and then I will control my diet."	Visualization of blood glucose level helps with behavioral changes: "I have to adjust my diet. After a nap in the afternoon, I will have some chia seeds, and I do not eat white rice in the evening. I eat less in general, and the reduction in the amount of food intake really has a great association with my blood sugar levels; I used to measure it in the morning and evening, but now I measure it only once a day. I was worried that the blood sugar was too high, but now the blood sugar has stabilized, and I do not measure so many times. Otherwise, my hand will hurt from measuring my blood sugar level"
Theme 2	Individual problem-solving motivation is a key to adoption: "All I can answer is that I do this for my own good! And I also want to know where the problem lies!"	Technology as a supervisor: "Of course, I would be more cautious about my diet because I am wearing it."; "One thing that I should pay attention to is that the device is still recording, so I have to be more careful about what I've eaten."	Motivation at enrollment is a determinant: "It is OK as long as there is improvement to the control of my blood sugar levels! I would like to try it as long as it can help control my blood sugar levels."; "No! Very few people have done this, and I asked many people and they did not know much about this. We are not doctors, so how can we know this? We do whatever the doctor tells us to do because it is too much of a bother to fill in the records."
Theme 3	__[b]	Technology as a useful tool to visualize the blood sugar results: "Although I have insulin injections, I have no idea about my blood sugar levels. This time, after wearing the device, I know my own blood sugar levels"	—
Theme 4	—	Technology as an obstruction: "Because I had an operation on my waist before, I could easily get a backache. I used to have a hot bubble bath in the morning, but I cannot because I am wearing the device. It is causing some inconvenience, as my activity has become less smooth in the morning."; "I feel it is very inconvenient! When I want to move things, I cannot use force. And I do not know how to use force because I am afraid I will break things."	—
Theme 5	—	Technology as a hint of disease progression: "I just feel that medication is enough. Why do I need to go through this?"	—

[a]CGM: continuous glucose monitoring.

[b]Not applicable.

Theme 2: Technology as a Supervisor

Besides serving as a reminder, it also played the role of a supervisor. Some participants noted that they felt supervised when they used the CGM. They realized that they had to follow the principles of a diabetes diet because the CGM could record everything they had done. Therefore, they ate less or did not have snacks during the trial. They followed the diabetes diet when wearing the CGM device:

> One thing that I paid attention to was that the device was still recording, so I had to be more careful about

> what I had eaten, and I think it's good because when I did not wear it [CGM], I did not know what I ate and what was happening to my body, and then when I wore it, it helped me record my blood sugar levels, and I knew I would like to eat less of something. I tried my best to eat more and eat better. [No. 06, age 56, female]

> It [diet] is normal, and I may be more restrained. I will control myself more when it comes to eating fruits or drinking beverages. [No. 10, age 67, male]

Theme 3: Technology as a Useful Tool to Visualize the Blood Sugar Results

The CGM device provided a visualized outcome of the participants' blood glucose levels. Most participants mentioned that they realized the relationship between their food intake and changes in their blood glucose levels. Some participants said that they had received health education, so they now realized what they should eat. However, the relationship between food intake and the changes in blood sugar was not clear until they participated in the trial:

> *This time, after wearing the device, I know my own blood sugar levels...In the past, I only measured my blood sugar levels once a week in the morning before breakfast. But this time, I know that blood sugar levels differ in the morning before a meal and before the time to go to bed...I did not know about this before...Because this device measures the blood sugar level every day in the morning and at night, I know that it is normal for my blood sugar level to be higher at 140 or 150 [mg/dl] in the morning. Otherwise, I used to wonder why it [blood glucose level] was so high despite my efforts to control my blood sugar level.* [No. 12, age 67, female]

Theme 4: Technology as an Obstruction

Though it acted as a reminder, a supervisor, and a visualizer, the CGM device also created some problems for some participants. To complete the trial, participants had to record everything that they ate; some participants could not complete it by themselves. They had to ask their family members for help:

> *Usually it is okay, but sometimes it is necessary for me to write the records. I don't have a high level of education, so sometimes, I have to ask my husband to help me write the records, so it's troublesome.* [No. 08, age 65, female]

In addition, 1 participant noted that he could only take a shower instead of taking a bath when wearing the CGM device. Owing to this, he could not relieve his back pain:

> *Because I had an operation on my waist before, I can easily get a backache. I used to have a hot bubble bath in the morning, but I cannot because I am wearing the device. It is inconvenient now that my activities have become less smooth in the morning.* [No. 05, age 61, male]

Moreover, the CGM device could also be an obstruction for participants. When they wore the device, their body movements were affected:

> *I feel it is very inconvenient! When I want to move things, I cannot use force, and I do not know how to use force because I am afraid of breaking things.* [No. 13, age 62, male]

Theme 5: Technology as a Hint of Disease Progression

For the participants, the CGM device was not only a medical intervention to improve health management but it was also a hint of disease progression. This medical intervention revealed when the participants' physical condition became so worse that the CGM device had to be used:

> *I am in a bad mood because I just feel that medication is enough. Why do I need to go through this?* [No. 03, age 62, male]

Can Continuous Glucose Monitoring Be an Effective Behavioral Modification Tool?

To answer this question, we explored the participants' behavioral changes before and after wearing the CGM device. We asked them whether their perceptions of CGM changed or if their disease management became different. We categorized the participants' answers into 2 themes as discussed below:

Theme 1: Visualization of Blood Glucose Level Supports Behavioral Change

Technology brought confidence and self-efficacy that helped the participants to measure their blood glucose levels more effectively. The participants had typically only measured their blood sugar in the morning in the past. However, some participants mentioned that they would like to measure it at different times in a day to observe the changes in their blood sugar levels over time:

> *I used to take a measurement in the morning, so I did not know that the blood glucose levels could be different at different time points...After wearing this, I want to measure my blood sugar levels before breakfast, lunch, and dinner.* [No. 12, age 67, female]

However, the opinions may have been very different because when the participants realized that glycemic control was stable through this technologic intervention and they had more self-confidence in glycemic control, they decreased the frequency of measuring their blood glucose:

> *I used to take a measurement in the morning and evening, but now I measure it only once a day. I was worried that the blood sugar was too high, but now the blood sugar has stabilized, and I do not measure it so many times. Otherwise, my hand will hurt from measuring the blood sugar level.* [No. 21, age 57, female]

It also helped visualize the blood glucose levels so that participants knew how to modify their dietary behavior. Participants changed the kinds of food that they ate or reduced the amount of food that they ate. In addition, they paid attention to their diet:

> *I have to adjust my diet. After a nap in the afternoon, I will have some chia seeds, and I do not eat white rice in the evening. I eat less in general. The reduction in the amount of food intake really has a great association with the blood sugar levels...Now, I also need to reduce my juice intake!* [No. 18, age 69, male]

> *I will start to change my life habits slowly! Because I have a table...My doctor just gave it to me too. From this, I can see when my blood sugar is relatively high or low and what I can or cannot eat. I will adjust my diet based on it.* [No. 12, age 67, female]

Theme 2: Motivation at Enrollment Is a Determinant

Participants' behavior while wearing the CGM device was related to their motivation to participate in the trial. One of the motivations was that they wanted to understand their physical condition and know how to improve glycemic control. The other was that they trust their doctors or they are embarrassed to reject a doctor's suggestion.

The more desire that the participants had, the more actively they participated in the trial. Some participants mentioned that they were willing to do anything that is good for their health, and the CGM device was no exception:

> *I would like to try it as long as it can help control my blood sugar levels...I will pay attention to my diet. I would like to try if it helps control my blood sugar levels when I make adjustments to my diet. From this test, I really find that there is quite an influence...It [adjustment of diet] has improved control of my blood sugar levels a lot. Look at my blood sugar levels. I have never had a level less than 100 [mg/dl].* [No. 01, age 61, male]

In addition to following the original trial procedure, participants may do something different from their normal food intake to achieve more changes in their blood sugar. This trial was like another experiment. In addition to their regular routines, participants may do something different to find a better way to control their blood sugar:

> *I mainly want to know how my blood sugar level can rise so much...I should go through a test to see what I should not eat...I even heard that there was a kind of herb that is good for the treatment of diabetes. I am planting this kind of herb. I thought, why not give it a try? Yesterday, I ate some pieces of the herb. This morning, I also ate some pieces, and my blood sugar level is indeed reduced.* [No. 18, age 69, male]

The participants' opinions on the CGM device were also associated with their motivation to participate in the trial. The participants who actively wanted to be involved in the trial were more cooperative during the trial. Despite many trivial details, they were willing to complete the trial. On the contrary, participants who passively participated in the trial were inclined to complain about trivial details and be in a bad mood:

> *Quite honestly, I think I am also a co-operative patient...but the control of my blood sugar levels is not very satisfactory...So, I want to find out the problem through this test and avoid it in the future to see if it can really improve the condition of my body...It (measuring the blood glucose level several times a day) is not so bothersome because I used to measure my blood sugar level each day. Although this device measures my blood sugar level at a slightly higher frequency, I do not need to pay attention to the time for measurement of my blood sugar level, so it does not affect me that much.* [No. 05, age 61, male]

> *I am in a bad mood because I just feel that medication is enough. Why do I need to go through this...I do not like the feeling of being controlled. My doctor told me that if I wanted to control my blood sugar level well, I had to go through blood glucose monitoring...And I did not dare to refuse him...I cannot go out for lunch because I need to monitor the blood sugar level after eating...I am afraid that I will lose my freedom!* [No. 03, age 62, male]

> *Very few people have done this (CGM), and I asked many people, and they did not know much about this. We just do whatever the doctor tells us to do...It [the experimental procedure] is too much of a bother to fill in the records. It's not easy to record what you have eaten if it was just a snack. For example, do I have to make a record even when I only have two or three peanuts? I think it is hard to record everything! This is too troublesome!* [No. 19, age 69, male]

Discussion

Principal Findings

This is the first study in a non-Western country exploring the impact of a professional CGM system on middle-aged and older patients with type 2 diabetes. Patients aged 45 years or older who received CGM-based counseling were interviewed. Older patients' perceptions related to incorporating technology into their diabetes care, attitude and behavioral changes related to the technology, immediately and 3 months after CGM usage, were explored. Gender differences were also found in this study.

Our findings suggest that the physician is the dominant and most effective information provider, and most of the participants gained access to this new technology via their physician. In addition, patients' trust in their physicians made them want to try this new technology because they thought that their doctor would choose the best management for them. In a past study, there was also some mention of this opinion. A qualitative study exploring medication use in seniors indicated that a doctor is a trusted authority. On the basis of this trust, people felt confident that their doctor was choosing medications best suited for them [20]. The attitude of health providers is a dominant factor in patient disease management as well [21]. In addition, health care personnel play a vital role in adoption of new technology. Doctors may be information providers, and they also increase access for patients to new technology.

However, physician attitude or insufficient training also can be a barrier to new technology use. Some endocrinologists view CGM as a waste of money or have little information about it. These negative perceptions also affect adoption of CGM in diabetes patients [22,23]. In our study, we explored another adverse effect that results from professional advice. One of our male participants reported that CGM could be a hint of disease progression. Therefore, his perceptions of this device were negative. We assess that this could be a negative effect derived from professional opinions. The misconception of disease progression may result from doctors' unclear explanations or information. Thus, these findings suggest a potential connection between professional advice and middle-aged and older patients' adoption of new technology. When it comes to application of new technology, professional authorities may play an important role.

In chronic illness management, social support plays a vital role. Sufficient social support benefits disease self-management [24]. In our study, the participants revealed that CGM could be a reminder or supervisor that helped them to follow their original diet plan. The device was like another person reminding them and helping them have better diet control. In a past study, it was also reported that insufficient social support or overbearing support is also a source of patient distress [25]. In addition to true interactions between people, technology is gradually influencing disease management. It can be a reminder to help patients adhere to their plan [26]. For these reasons, we suggest that technology may be an effective part of chronic illness management.

In our study, we also found a gender difference in the attitude toward technology as indicated in previous research [27]. There was a higher percentage of women compared with men who reported that CGM played a role as a reminder or a supervisor to help them with dietary control. Among all participants, 4 of 7 (57%) women had this perception, whereas only 4 of 13 (30%) men had the same opinion. A previous CGM study for women showed the same result. The majority of women reported they were interested in changing their diabetes-related self-care behavior [28]. In a past study, it was revealed that social support is also gender-related. For men, coping with diabetes is strongly affected by their living spouse, and men receive more support from their spouse for dietary needs than women receive from their spouse [24,29]. However, females actually exhibit a greater psychological impact of diabetes than males [29]. In addition, females may gain more benefits from social support than men [30]. Under these circumstances, we suggest that women may need more social support to have better self-management. Therefore, we suggest that technology intervention may make up for women's lack of social support.

Limitations

The limitations of this study include the fact that it was a small, homogenous sample. All participants were from a city in southern Taiwan. For this reason, access to health education or disease information was almost the same for the entire sample. In addition, the participants were only partially selected. Our study had to be reviewed by the Institutional Review Board and Ethics Committee. Therefore, the participants were all informed before they were recruited. These participants might have been more motivated to use new technology. Thus, there might have been a bias. Moreover, the interviews were conducted individually by 2 people, and every interview did not take an equal amount of time, which might have led to some bias.

Conclusions

In conclusion, this study identified perceptions and usage experience of professional CGM in middle-aged and older patients with type 2 diabetes. The participants' problem-solving motivation and the advice of professionals were determinants of adoption of a new technology. Professional CGM helps visualize glucose control generally. We also found that technology intervention could be an effective behavioral modification tool and support system with the 3-month follow-up interviews. In addition, there was a higher percentage of women compared with men who reported that CGM played a role as a reminder or a supervisor to positively help them with dietary control. As type 2 diabetes is a highly behavioral modification and support-needed disease, and the fact that social support is gender-related, our findings that a technology intervention can make up for lack of social support, especially for women, warrant future verification.

Conflicts of Interest

None declared.

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Abbreviations

CGM: continuous glucose monitoring
HbA$_{1c}$: glycated hemoglobin
IBGM: internet blood glucose monitoring
RT-CGM: real-time continuous glucose monitoring
SMBG: self-measured blood glucose