Chapter 2

Empowering Diabetes Patient with Mobile Health Technologies

Matjaž Krošel, Lana Švegl, Luka Vidmar and
Dejan Dinevski

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/64620

Abstract

Chronic diseases, especially diabetes mellitus, are huge public health burden. Therefore, new health care models for sharing the responsibility for care among health care providers and patients themselves are needed. The concept of empowerment promotes patient's active involvement and control over their own health. It can be achieved through education, self-management, and shared decision making. All these aspects can be covered by mobile health technologies, the so-called mHealth. This term comprises mobile phones, patient monitoring devices, tablets, personal digital assistants, other wireless devices, and numerous apps. Many challenges of diabetics can be addressed by mHealth, including glycemic control, nutrition control, physical activity, high blood pressure, medication adherence, obesity, education, diabetic retinopathy screening, diabetic foot screening, and psychosocial care. However, mHealth plays only minor role in diabetes management, despite numerous apps on the market. Namely, these apps have many shortcomings and the majority of them does not include important functions. Moreover, these apps lack the perceived additional benefit by the user and the ease of use, important factors for acceptance of mHealth. Studies of diabetes apps regarding usability and accessibility have shown moderate results. Beside improvements of apps usability, the future of diabetes mHealth lies probably in personalized education and self-management with the help of decision support systems. At the same time, work on artificial pancreas is in progress and smartphone could be used as user interface.

Keywords: mobile health, diabetes, empowerment, smartphone, chronic disease management

1. Introduction

Aging and chronic conditions represent a huge burden on the health care budgets. Moreover, in the future this burden will only increase [1]. At the same time, the patients require a better service, while there are fewer health care professionals and lesser resources. The states currently act mainly in two dimensions. On the one hand, they are strengthening their efforts on prevention. They develop or update existing programs, which promote healthy and active life styles. On the other hand, they are transforming the existing health care. Namely, the health care systems as we know them were developed to treat the acute diseases. However, the chronic diseases spent more than 70% of the health care budgets [2, 3]. The prevention programs can prolong the healthy period of each individual, but some chronic diseases, such as diabetes, cannot eliminate. Therefore, there is a need for transformation of the existing health care whose goals are better health results, better quality of service and quality of patient life, and economic feasibility. This transformation is as follows [2]:

- from the health care model centered on acute medical care to the model adopted to the needs of chronic patients,
- from reactive model to proactive model to cure, care for and prevent based on risk factors,
- from passive patients to a model with a patient in the center, actively managing his disease,
- from a fragmented model with lack of coordination to a model enabling continuity of care, and
- from activities primarily in acute hospitals to activities in more suitable environments, such as homes.

The key enablers for such transformation are patient empowerment, use of information and communications technology (ICT), integrated care, and adopted business models.

This chapter explores the concept of empowerment of diabetes patients by presenting current and future possibilities of mobile health technology.

2. Diabetes mellitus

Number of diabetes patients around the world has reached 415 million and it is predicted to climb up to 642 million by the year 2040. Diabetes can also be linked to around 5 million deaths each year and it is associated with high financial burden, since health spending on diabetes accounts for around 12% of total health expenditure worldwide. The costs include increase use of health services as well as loss of productivity or disability and are estimated to range from 673 billion USD to 1197 billion USD [4]. With such troubling predictions, we are obligated to look for new methods to facilitate patient care. Introduction of new methods should be done with the understanding that more than 95% of diabetes care is done by the patients themselves [5]. This is just one of several reasons why diabetes patients are excellent candidates for managing their disease with the help of mobile health technologies (mHealth) and why this may improve many aspects of personal and public health.

Diabetes is medically defined by the following criteria: patient fasting plasma glucose level ≥126 mg/dl (7.0 mmol/l) or HbA1c (glycated hemoglobin) ≥6.5% or patient plasma glucose level 2-h after OGTT (oral glucose tolerance test) ≥200 mg/dl (11.1 mmol/l) or patient random plasma glucose level ≥200 mg/dl (11.1 mmol/l) [6]. After the diagnosis, diabetes patients need to endure life-long management of their disease, which include medications and significant lifestyle changes. Disease progress should be monitored with the help of health care professionals in order to ensure prevention and quick diagnosis of long-term complications of hyperglycemia. Most commonly seen diabetes complications are retinopathy with a potential loss of vision, nephropathy that can result in renal failure, peripheral neuropathy leading to foot ulcers, Charcot foot and amputation, autonomic neuropathy that can causes gastrointestinal, genitourinary, and cardiovascular symptoms. The patients with a chronically elevated glucose level have high incidence of atherosclerotic vascular changes, which cause development of peripheral arterial disease, cerebrovascular, and cardiovascular complications [6, 7]. Number of complications can be reduced, if patients maintain good glycemic control. Every patient who reduces HbA1c level for 1% decreases the risk of microvascular complication for 37% and the risk for diabetes related deaths for 21% [8].

3. Adherence to treatment

World Health Organization defines adherence as an extent to which a person's behavior: taking medication, following a diet, and/or executing lifestyle changes, corresponds with agreed recommendations from a health care provider [9]. One of the key challenges in diabetes management is a lack of adherence to medication regime and lack of lifestyle changes. Adherence to oral hypoglycemic agents is between 36 and 93% for the first 9–24 months of treatment and adherence to insulin treatment for type 2 diabetes patients is between 62 and 64%. Patients even less complain when it comes to dietary and other lifestyle recommendations [10, 11]. Regardless of the type of treatment, it was proven that introduction of self-monitoring of blood glucose level is associated with better glycemic control [12], but there are still around 29% patients treated with insulin, 65% patients treated with oral hypoglycemic agents, and 80% patients treated with dietary restriction, who do not practice self-monitoring or they do it less than once a month [13]. Poor adherence is also a public health issue. For every 10% increase in adherence, there is 8.6% decrease in annual health care cost. Furthermore, there is evidently a link between number of hospitalizations and adherence to medication therapy, which is reduced by 23.3% when adherence had increased from 50 to 100%. Even more evident reduction of 46.2% is seen in number of emergency department visits. Both events, i.e., number of hospitalization and emergency department visits are associated with lower costs [14, 15]. When dealing with nonadherence, it is valuable to consider various reasons why this phenomenon occurs. It can be attributed to demographic factors, psychological factors, social factors, medical system factors, disease and treatment characteristic, but mostly it is a result of combinations of multiple factors [11, 16]. For example, glycemic control and treatment outcomes are less promising among racial minorities, men and people with depression or anxiety disorders [17, 18]. Those differences emphasize the importance of individualized and patient-centered care.

4. Concept of empowerment

Patient empowerment is a paradigm of transferring the responsibility of patient's health care in the hands of patients. Such paradigm is in contradiction with the traditional health care where the care was in the hands of the medical staff.

Compliance and adherence are concepts that arise from an idea of patient submitting and agreeing with health professional, who acts as an authority, whereas empowerment promotes patient active involvement and control over their own health [19].

The empowerment can be achieved through education, self-management, and shared decision making.

To obtain satisfactory outcome, there is more to be done than just encourage patients to self-manage their chronic disease. Patients need to be educated about their disease, motivated, provided with patient-centered care, which means that self-management plan needs to be tailored to fit patient priorities, goals, resources, culture, and lifestyle [19].

The education typically occurs at the clinic by the doctor and/or nurse. At Stanford School of Medicine, a Chronic Disease Self-Management Program (CDSMP) [20] was developed which empowers patients through a series of workshops in community settings. Its success is evident in Denmark, which decided to implement it in its health care. As a result, Danish patients are the most empowered [21]. This program was also used in EU project EMPOWER [22].

While face-to-face patient education has positive effects, not much work has been done to evaluate the effect of virtual education. Moreover, patient knowledge is a necessary, but not a sufficient factor for change in the self-care behavior [23]. Patients require self-management support. It can be achieved through face-to-face interaction, through self- and telemonitoring and virtually [24–27].

Collaborative decision making represents collaboration and exchange of knowledge among patients, formal and informal care givers. Because it currently occurs in face-to-face meetings in most cases, there is no evidence for the effects of virtual collaborative decision making.

The goal of such efforts is to shape individuals that make rational health care decisions regarding their health and wellness, are less depended on health care service and contribute to more cost-effective use of health care resources [28].

Finally, in the diabetes treatment, notions of compliance and adherence were replaced with the concept of patient empowerment [29]. With Diabetes Empowerment Scale, significant correlation between level of empowerment and better medication adherence, extensive diabetes knowledge, improved general diet and exercise, blood glucose control, and foot care, can be established [30]. In diabetes management, mobile health technologies are already offering different means for introduction of the concept of empowerment into patients' everyday life.

5. Use of information communication technologies (ICT) for patients with chronic diseases

Patients with chronic diseases need to monitor and record several biometric health parameters. For this purpose, in current health care system, they mainly note observations on a paper, although most devices in use enable storage of such biometric measurements. While there are issues with reading noted values from the papers or even with losing the papers, there are issues with transferring the stored data on the devices to general practitioners (GPs) or specialists. Moreover, the doctors would appreciate to monitor more parameters that are relevant for a holistic care.

On the market, there are devices that can automatically measure and transfer the measurements to the smartphones and dedicated servers: Fitbit wristlets measure user activity and sleep periods [31]; BitBite measures user nutrition habits [32]; iHealth [33], VitaDock [34], VPD [35], and Abbott [36] products measure temperature, blood pressure, pulse, blood oxygen saturation, and glucose level. The current trend is geared toward wearables and gadgets that help diagnose very specific diseases, such as peripheral neuropathy [37] and retinopathy [38], toward gadgets that can measure several parameters [39] and toward integration of functionalities from gadgets to smartphone applications, such as in Google Fit [40] and in Moves [41]. These applications perform comparably well as standalone devices [42].

Furthermore, there are numerous smartphone applications, working with manual data input or data from previously mentioned devices, that assist users in managing their health [43, 44] or diabetes in particular [45, 46]. Such applications do not only display the status of health parameters, but also provide personalized recommendations based on the input data. They mostly encourage users to change their behavior [47].

However, wearable devices and smartphone applications are only facilitators and not drivers of patient empowerment. The design of engagement strategies is more important for successful use and potential health benefits of these devices than the features of technology [48].

Several pilots have been conducted, suggesting positive effects on health and diabetes care, and a need for 24/7 support [49–51]. However, in use, there are mainly only solutions that enable patients to informatively monitor their health status. Solutions that would be used as a part of the general health care service are in the stage of pilots and are only very rarely deployed as part of the standard practice.

6. Why mobile health?

Mobile health is defined as a use of mobile communication devices, which include mobile phones, patient monitoring devices, tablets, personal digital assistants, and other wireless devices for health services, and information [52]. Currently, growing use of those devices can be seen in practically every part of the world. Number of mobile phone owners in the United States has reached 92% of a population and even number of smartphone owners has grown to 68%, while 45% of people own a tablet computer. Desktop or laptop computers were bought by 73% of Americans [53]. Surprisingly, similar rise in mobile technology use is also recorded among people in developing countries, where average share of people with mobile phones is around 83% [54]. With a vast majority of world population having an access to some type of mobile technology, this can certainly become a widely used to deliver deferent health care solutions to people. Role of mHealth is very broad and includes education and rising awareness, remote data collection, remote monitoring, communication with health care workers, support with diagnostic and treatment, and tracking diseases and epidemic outbreaks [55]. Most of these tasks are already performed by various mHealth applications for diabetes self-management.

7. Features of diabetes apps

There are different classifications of diabetes app features and in this section we present some of them.

Review of accessible diabetes applications has shown that they mostly focus on blood glucose monitoring, medications, physical exercise, and diet management, while they also include other features such as education, communication, weight or BMI and blood pressure tracking, integration with public health records, decision support systems, and social networking. Blood glucose monitoring is available in all reviewed applications, while other features are more rarely present. Educational tools are brought to use in just 18% of applications and only around 30% of applications offer means to monitor weight, blood pressure, and physical exercise [56]. Still, among all medical conditions, diabetes with weight control represents the most addressed medical issue by mHealth applications in mHealth research [57].

In a recent systematic review, 53% of apps offered documentation function (recording and displaying data), 17.8% analysis function (the possibility to analyze the recorded data and to graphically display the results), 11.4% reminder function (reminds the user of its periodic, predefined medication), 34.5% of apps offered an information function (inform about the illness). Data forwarding/communication function (opportunity to send the recorded data) was present in 31.1% of apps. Surprisingly, only 8.8% of the diabetes apps provided an advisory function (use of the recorded data to create individualized advice) or any other kind of therapeutic support. Besides, the previously described functions, 14.5% of the apps included suggestions for recipes suitable for the needs of diabetics. The majority of apps, i.e., 54.1% were limited to only one function, while there were only 28.2% with two and 17.7% with three and more functions [58]. In another classification, features of apps were grouped into three classes on the basis of prevalence. In class A, there were insulin and medication management, communication and patient monitoring by primary care providers, diet management, and physical activity. Class B included weight management, blood pressure management, and connection to personal health record (PHR). In class C, there were education, social media, and alerts. Class A comprised four major features and class B had significantly higher prevalence than class C [59].

mHealth research platform *Few Touch Application* (FTA) was developed to support management of diabetes. Applications and studies based on FTA allow automatic monitoring of blood glucose information, receiving short message service information about type 1 diabetes, mobile diary for type 2 diabetes, sharing diaries with doctor or nurse, mobile diary for type 1 diabetes, a food picture data, transfer of physical activity data on mobile phone, nutrition advices, context sensitivity, and modeling of blood glucose. Performance of each of the 10 FTA-based apps was analyzed and the conclusion was that all FTA apps are beneficial [60].

In the next sections, we will present 11 problems of diabetes disease that can be addressed by mHealth.

7.1. Glycemic control

Monitoring of blood glucose level is a base function of all available mHealth diabetes applications, because even without technology interventions self-monitoring of blood glucose (SMBG) is still an integral component of daily diabetes management, especially for insulin-treated patients [56, 61]. Unstructured SMBG is not recommended and does not produce the same results as structured SMBG, which links to behavioral changes, optimization of therapy, and improved clinical outcome. An example of such structured SMBG is a 7-point glucose profile, where blood glucose is measured every day of the week preprandially, postprandially, and at bedtime [62]. A pilot of such structured SMBG demonstrated a reduction in HbA1c levels up to 1.2% in 12 months [63]. To help patients in keeping up with structured SMBG, mHealth offers personal goal setting and various types of reminders [64]. Most commercially available devices for glucose monitoring enable patients to store and follow their blood glucose pattern. For this, patients need to transfer measurements to a computer through an USB cable or to a mobile phone with a direct connection through Bluetooth or Wi-Fi. Even more accurate glucose profile can be obtained with a use of continuous glucose monitor [61]. Regardless of a type of a mHealth intervention used, there is evidence in its positive impacts on reduction of HbA1c values by a mean of 0.5% over 6 months [65]. However, a review of 24 papers has shown that the effectiveness of mHealth interventions (blood glucose reading and transmission to server) measured in HbA1c value was inconsistent for both types of diabetes [66].

7.2. Nutrition control

For education, most of the technologies used for nutrition therapy rely on videoconferencing, while for food tracking and food selection various mobile apps [47]. Distinct features are being formed among behavior mHealth modalities. Food intake can be recorded to determine the quantity of calories consumed each day and the targeted quantity of calories automatically adjusted, based on patient's daily physical activities [67]. More widely adopted are different nutrition databases containing a rage of food items, including different brands and restaurant food, and real-time calculations of consumed calories. Similarly, there exists also a possibility to scan the barcode of brand names to see the nutrient content [47]. Growing number of possibilities provide a new generation of mHealth devices also known as wearables. For example, in diet self-management wrist monitors and electronic utensils can be used to track the amount and speed of bites, but such devices are practically not used yet [68]. Furthermore, mHealth may enable calories calculations with recognition of food from photography in free-living conditions. Even more promising are mobile applications that suggest appropriate meal based on preprandial blood glucose reading, which can facilitate patients' educated decision making [64].

7.3. Physical activity

Sixty nine percent of diabetes patients describe their exercise practices as nonexistent or less than recommended level [69]. It is recommended that adult patient with diabetes perform at least 150 min of moderate-intensity aerobic physical activity per week, spread over at least 3 days and with no more than two consecutive days without exercise [70]. For patients to monitor the extent of their daily physical activity, mHealth offers solutions in a form of body-worn activity monitors. Most easily accessible are pedometers, but besides number of steps taken they do not measure other forms of physical activity [64]. Meanwhile, accelerometers with a combination of gyroscope can record wider range of movements and accuracy of recordings is not dependent on person's body position [71]. When tested, people with access to fully automated system performed on average for 2 h and 18 min per week more of physical activity than people without it [72]. Wearable sensors still need to be complemented with education, planning, and feedback tools to successfully promote physical activity. Effectiveness of mHealth intervention was shown in improved daily number of steps, which was done by setting an achievable goal, providing real-time feedback about the amount of burned calories, and showing recorded progress. This raised the number of steps by 22% in 8 weeks [73].

It was observed that insufficient number of currently evaluable mHealth applications incorporate evidence-based behavior change techniques. This is especially true for techniques, such as relapse prevention, teaching to use props, time management, and agreement to form behavior contract [74].

7.4. Weight loss

Obesity should be diagnosed according to body mass index (BMI). BMI classes are normal weight (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2), obesity class I (30–34.9 kg/m^2), obesity class II (35–39.9 kg/m^2), and obesity class III (≥40 kg/m^2). For Southeast Asians and Asian Indians, lower BMI cut-points may be appropriate. Lifestyle modifications including behavioral changes, reduced calorie diets, and appropriately prescribed physical activity should be implemented as the cornerstone of obesity management [75]. Weight loss can be achieved with 500–750 kcal/day reduction that means intake of 1200–1800 kcal/day depending on sex and baseline body weight [76]. Raised BMI, i.e., above 25 kg/m^2, is seen in more than 75% of diabetes patients [77]. Patients with high BMI and diabetes are significantly more likely to have poor glycemic control [78]. Overweight individuals with diabetes are encouraged to lose at least 5–10% of their weight, because this importantly reduces most cardiovascular risk factors, but it is worth mentioning that lager weight loss (10–15%) has even greater benefits [79]. Reviewed mHealth applications offer means to help achieve this recommendation by monitoring and facilitating physical activity (41% of the applications) and by improving users' diet (68% of the applications) [56]. An evaluation of 137 diabetes apps showed, that only 39% of them offered weight tracking [59]. Self-monitoring of weight and of body composition by using weight scales can now be accomplished wirelessly with mHealth apps or computer applications. This minimizes the burden on the user, while it also minimizes the error in data transcription. Tracked weight and fat mass can be graphically analyzed by the patient or health care practitioner [47].

SMS interventions were investigated to promote change in diet and physical activity. Small and short randomized controlled trials proved significant weight loss, while larger and longer studies showed no statistical significance [80].

Researchers investigated dietary self-monitoring-based electronic interventions using personal digital assistants (PDAs), electronic portable devices that share some of the features of mobile phones. PDA in the study was equipped with dietary and exercise software with and without feedback message. Patients were enrolled in three groups: PDA alone, PDA with feedback (feedback algorithm that provided daily messages tailored to their entries and provided positive reinforcement and guidance for goal attainment), and paper diary/record. All participants had statistically significant weight loss, but PDA group combined with feedback had the highest proportion of participants achieving greater than 5% weight loss in six months [81].

Studies incorporating podcasts compared to podcasts that included prompting by mobile app and interaction with study counselors and other participants on Twitter, did not show enhanced weight loss in the latter group [82].

Interventions delivered by smartphone app, website, or paper diary were also compared. App incorporated goal settings, self-monitoring of diet and activity, and feedback via weekly text message. The website group used commercially available slimming website. Trial retention, adherence, and achieved weight loss were significantly higher in the smartphone app group [80].

7.5. Blood pressure control

Elevated blood pressure is a common condition coexisting with diabetes and it is a clear independent risk factor for the cardiovascular complications. To reduce the risk, blood pressure should be routinely monitored and maintained at a targeted level. Recommended systolic pressure for diabetes patient is <140 mmHg and diastolic pressure <90 mmHg. Home-monitoring is greatly encouraged, because it is a way to exclude white coat hypertension and because research suggested better correlation between at home measurements and cardiovascular risk than office measurements [83]. Among reviewed diabetes applications, 23% of them currently offer means of self-monitoring of blood pressure [56]. Monitoring blood pressure with the help of mHealth program may detect hypertension patterns that would otherwise gone unreported [22]. Fully automatized blood pressure readings, which are immediately stored in mHealth device and send to a health care provider, enabled to 51% of diabetes patient to reach the targeted blood pressure level. This is a significant improvement compared to 37.5% of general diabetes population that succeed in lowering their blood pressure. Such improvement was achieved also due to by inclusion of daily reminders, alerts in a case of concern-reassign measurement and linkage to patient support system [84]. Home-monitoring alone does not produce the same results, proving telemedicine equal, but not more effective than standard approach, so this needs to be taken into consideration for future mHealth design [85].

7.6. Medication adherence

Previously, already discussed lack of adherence to pharmacological intervention in diabetes patients is an issue addressed by approximately 76% of reviewed mHealth applications [56]. One of the commonly reported barriers is patient forgetfulness, when it comes to medication intake regime. Mobile health technologies can offer different solution to this problem. Daily automatic electronic or text-message reminders may improve medication intake [86]. Those reminders can be upgraded by the use of real-time medication monitoring, which is possible with a use of electronic medication dispenser that records date and time of each opening. Consequentially, alert is only send in a case of forgotten medication dose. A trail confirmed that a baseline adherence of around 62% improved to 79.5% adherence after 1 year of use. Long-term effectiveness of this mHealth method peaked at 80.4% medication adherence, whereas control group adherence remained in a range of 68.4%. Majority of patients that used real-time medication monitoring also agreed that this method supported higher awareness of their medication use and reported positive experience with receiving SMS reminders [87, 88]. Considerable amount of patient, who tested real-time monitoring devices, were glad that physician knew if they took their medication and were reassured by technology supported communication [89].

7.7. Education

Diabetes education is a key element in patient care. To reassure adequate results, effective education strategies can be found in National Standards for Diabetes Self-Management Education and are worth applying to mHealth methods [90]. Even limited amount of education can result in improved weight control and potentially reduced cardiovascular risk [91]. Initial comparisons between in person diabetes education and education administrated through telemedicine already demonstrated a feasibility and equal effectiveness of technology supported methods [92]. Most diabetes self-management applications do not integrate educational information. When available, such information is often generic and is not personalized to the individual patient. This is more prominent in commercial applications [56]. Education and personalized feedback are still underdeveloped features, included in less than one third of reviewed mHealth applications. Only 20% of reviewed applications had an education module, and only 26% of these met the criteria for personalized education or feedback. Task of personalizing rapidly growing number of information is challenging, but it may be largely beneficial for diabetes patient [59]. Most widely used mHealth method for diabetes education is SMS. Meta-analysis of current findings has shown that mobile SMS education can improve glycemic control. The glycemic control is even better if diabetes education is done by a combination of SMS and internet methods, i.e., 86% effect in comparison with 44% that is achieved by SMS alone [93]. Positive results of e-mail and SMS education can also be seen in improved quality of life [94].

Numerous applications are available helping healthy people or people with risk factors to assess their risk for developing diabetes type 2 in the future. Only a few of these apps disclose the name of the risk calculator used for assessing the risk of diabetes, therefore the quality of their calculations is questionable [95].

7.8. Diabetic retinopathy screening

Diabetic retinopathy represents most frequent cause of newly occurring adult blindness. Incidence of diabetic retinopathy is highly depended on duration of diabetes itself. Among population with type 2 diabetes cumulative incidence after 4 years is estimated to be 26%, 38.1–41.0% after 6 years and 66% after 10 years [96]. Comprehensive eye examination should be performed after diabetes diagnosis and repeated every 2 years, if there are no visible changes, or annually, if initial retinopathy changes are already present [97]. To keep up with this requirement even with patient in remote and isolated areas, low cost smartphone-based intelligent system integrated with microscopic lens was developed and tested. System detects retinal abnormalities by a method of comparison with medical image database. Early testing has promisingly shown more than 87% accuracy rate in retinal disease detection [98].

7.9. Diabetic foot screening

Diabetic foot is a main cause for nontraumatic lower limb amputation and precedes 85% of the cases. Approximately 15% of diabetes patients will develop diabetic foot ulcers in their lifetime [99]. It is recommended for all diabetes patients to perform annual extensive foot examination to identify risk factors predictive of foot ulcers. Patient should be screened for signs of peripheral neuropathy and peripheral vascular disease, simultaneously paying attention to identify other risk factors such as foot deformities, past foot ulcers, visual impairment, and cigarette smoking [97]. Currently, researched mHealth method to facilitate foot care is using high quality photography to diagnose foot ulcers and preulcerative lesions. Trained professional can diagnose visible diabetic foot changes in valid and reliable manner, which implies methods usability as a monitoring tool in home environment [100]. Originally developed was a method for wound area measurement. The wound margins are recognized with the help of smartphone. First, the wound contour is copied on the foil. The area is then measured with smartphone app and compared with previous measurements [101].

7.10. Psychosocial care

Patients with diabetes should regularly be assessed for their psychosocial well-being. Care should include assessment of their attitudes about the illness and prognosis, mood changes, satisfaction with quality of life, financial, social and emotional conditions, and possible psychiatric disorders (depression, distress, anxiety, eating disorders, dementia). Screening is recommended for depression and cognitive impairment for older than 65 [76].

Telemedicine study researching depression and glycemic control in elderly showed a weak relationship between depression and HbA1C, but depression did not prospectively predict change in glycemic control [102]. In another study, web-based depression treatment for diabetics using cognitive behavior therapy was effective in reducing depressive symptoms, diabetes-specific emotional distress, while it had no benefit on glycemic control [103].

Telephone-based cognitive assessment (TBCA) was previously performed by conventional telephone. Because of better understanding of cognitive impairment, there is a possibility of more accurate TBCA. It needs more complex features of telephone which are easily achieved with the use of smartphones [104].

7.11. Personal health record (PHR)/electronic medical record (EMR) and social media integration

PHR is an internet-based set of tools that allows people to access and coordinate their lifelong health information and make appropriate parts of it available to those who need it [105]. Electronic medical record (EMR) is an electronic record with documents of patient's treatment in a clinic. Electronic health record (EHR) is a summary of individual's lifetime health status and care. Terms EMR and EHR are often used interchangeably [106].

Overall, 21% of commercial applications support synchronization of data with PHRs. Half of reviewed studies have integrated PHR with EMR and provide both patient and physician Web portal, whereas other included either a patient view or a clinician view of the EMR [56].

Social media integration is also emerging function of diabetes apps. It can help patients find similar users and communities in a dynamic fashion. But the majority of apps only provides links to their groups in well-known social networking sites such as Facebook and Twitter or maybe provides an account to a forum [59].

8. Usability, accessibility, and acceptability of diabetes apps

In a study of feasibility and acceptability of PDA-based (personal digital assistant-based) dietary self-monitoring of diabetes patients at the time of advent of the first smartphone high percentage of participants reported that they found PDA-monitoring useful, that the app was easy to use and that feedback was easily understandable [107]. In another study with PDAs, several limitations were found that may have contributed to perceived frustration including usability, data loss/errors (especially mistyped numbers) and time constraint (time consuming and tedious handling) [108]. A new study revealed that the perceived additional benefit and the perceived ease of use had the strongest impact on acceptance of diabetes smartphone technology by patients 50 or older. Less important factors were previous experiences, health status, support, confidence in own technical knowledge, perceived data security, and fault tolerance. The target group of diabetes patients aged 50 or older is a rather heterogeneous one and their needs are highly heterogeneous due to differences in previous knowledge, age, type of diabetes, and therapy. For that reason, it is impossible to address the needs of all diabetes patients adequately with one diabetes app in order to gain an additional benefit. Therefore, the contents of a helpful diabetes app should be individually adaptable [109]. There is a lack of systems that can perform automated translation of behavioral data into specific actionable suggestions that promote healthier lifestyle without any human involvement. The first attempts were made to create personalized, contextualized, actionable suggestions automatically from self-tracked information [110].

Ten percent of all available apps in 2013 were evaluated within usability evaluation by three experts considering the special requirements of diabetes patients age 50 years or older. Four main criteria were evaluated, being ″comprehensibility,″ "presentation," "usability," and "general characteristics." The main criteria, "comprehensibility," rated best. In particular, the elderly benefit from easy, understandable semantics and easy, comprehensible, and interpretable images and depictions. It can lower inhibition thresholds, especially during the first time of use. The same is true for the influence of "easily understandable feedback" and an "intuitive usability" (main criterion "usability"). However, these two subcriteria performed worse within evaluation. Test of accessibility features indicated a very good operability of the screen readers. The criterion "fault tolerance" rated worst. Especially, inexperienced (elderly) users often have difficulties with inputting data. Some errors are unrecoverable or even cause the application to shut down [58].

9. Type 1 diabetes mellitus

We have to say some words about type 1 diabetes mellitus. We described until now mobile health interventions irrespective of the diabetes type. Because type 2 diabetes is much more widespread, studies included mostly or exclusively type 2 diabetes patients.

Young people with type 1 diabetes have many ideas and can help improve services and their own health-related quality of life. However, their lifestyle and their use of Web and smartphones to cope the disease are not well researched [111].

A systematic review was carried out, focused on the ability of mobile health tools to grant patients with type 1 diabetes greater glycemic control. The tools investigated took a variety of forms and provided a number of different services to a diabetic patient. The indicator demonstrating the intervention to be successful was HbA1c and it was decreased in majority of studies, but not all values were statistically significant. In addition, prospective studies were predominantly used instead of randomized controlled trials [112].

Qualitative interviewing and exploring how young people with diabetes type 1 make use of technology in their lives and in relation to their condition and treatment, was made. On that basis, many suggestions to develop apps were found including issues such as alcohol and diabetes, hypoglycemia and diabetes, illness and diabetes, and Twitter use for diabetics. All listed suggestions were taken forward for prototyping, with alcohol and diabetes being developed as clinically approved app. There were also many other issues suggested, that were not prototyped [111].

In UK, a competition for teams including at least one young person with diabetes to develop an app, that might help this group of patients in preparation for their diabetes appointments, was conducted. After the development, other young people with diabetes were invited to choose, test and review new apps. The competition proved successful, showing the app designers and developers a need to develop a range of new functions [113].

Insulin calculator apps for patients with diabetes were scrutinized, because self-medication errors are recognized source of avoidable harm. Users are at risk of both catastrophic overdose and more subtle—suboptimal glucose control. In a research, considering input, only 59% calculators included clinical disclaimer and only 30% documented the calculation formula. 91% lacked numeric input validation, problems were also with calculation with missing values, ambiguous terminology, even with numeric precision. Considering output, 67% of calculators carries a risk of inappropriate output dose recommendation that either violated basic clinical assumptions or did not match a stated formula or correctly update in response to changing user input. It is advised, that health care professionals should exercise substantial caution in recommending unregulated dose calculators to patients and take care for proper education about possible threats [114].

10. Doctors' involvement

Little attention has been paid to physicians' intentions to adopt mobile diabetes monitoring technology. Japan study showed that overall quality (system quality, information quality, and service quality) assessment does affect doctors' intention to use this technology, but only indirectly through perceived value. Net benefits (both ubiquitous control and health improvement) seem to be also a strong driver in both a direct and indirect manner [115].

Combined smartphone-based logging of different health parameters (e.g., blood sugar logging, insulin dose logging, bread unit logging, activity logging) can of course help doctor (diabetologist) in solving glycemic control problems. With these data, diabetologist can make individualized recommendations for every patient [116].

11. Economic effectiveness

It was establish that standard, technology unsupported, diabetes interventions are cost-effective. Effective base therapy typically costs up to $50,000 per each quality adjusted life year gained [117]. Activities that focus on intensive lifestyle changes, universal opportunistic screening for undiagnosed type 2 diabetes, intensive glycemic control, annual screening for diabetic retinopathy were proven to cost ≤$25,000 per life year gained or per quality-adjusted life year, what categorizes them as very cost-effective [118]. If there is to be expected that mHealth interventions will be introduced in everyday diabetes patients' care, they need to show themselves to be more cost-effective than standard treatment. In other words, they should cost less than an amount that we are already willing to pay for diabetes treatment. Current diabetes cost-effectiveness studies are sparse, but promising. Findings of one such study demonstrated annual cost decrease by using mHealth glucose meter with a support of disease management call center that outweighed higher program costs by several-folds. Implementation of technology supported care meant $50 per patient per month higher expenses than standard care, however in a year's time it was possible to register $3384 cost decrease compared with an increase of $282 among those with previously established course of treatment [119]. Immediate cost reduction after implementation of telehealth is primarily due to the absence of transportation costs per patient visit to outpatient clinic and productivity savings, because of eliminated need for frequent work absences. More substantial medical savings can be seen with a long term use [120]. Furthermore, it is reasonable to predict lowering of medical cost with growing number of diabetes patient included in automated telephone-linked interventions. For illustration, delivery of mHealth solution to 10,000 patients instead of 1000 can reduce expenses from £444 per patient to £301 [121]. In other economic evaluations, new management methods were determine to be associated with higher cost per quality adjusted life year and not cost-effective addition to standard care. This economic model argues that even with 80% reduction in equipment cost and full utilization of the telehealth service the probability of cost-effectiveness would only reach 61% at the £30,000 threshold of willingness to pay [122]. Still, individual research results are too heterogeneous to enable extraction of significant meaning regarding a possible medical expenditure reduction with continuous use of mHealth solution [123].

12. Future trends

Clinical decision support systems are active knowledge systems using two or more items of patient's data to generate case specific advice. It is in majority of cases standalone technology or integrated in provider's information system and is used by doctors or other medical staff [124]. Many mobile decision support software apps for smartphones are now available for diabetes and are intended to assist patients to make decisions for themselves in real time without having to contact their health care provider. For many minute-to-minute decisions, the questions are not sufficiently significant to warrant contacting a health care provider and there is insufficient time to wait for a reply. Mobile decision support apps can be helpful to assist patients to identify data patterns and make it easier for them to come to an immediate decision on their own [52]. With the advent of minimally invasive subcutaneous continuous glucose monitoring increasing academic and industrial effort has been focused on the development of SC-SC (subcutaneous-subcutaneous) artificial pancreas systems, using continuous glucose monitoring coupled with continuous subcutaneous insulin infusion. Next step is use of mobile system as user interface which is controlled by the patient. The interface is based on patient's commercial mobile phone [125].

13. Conclusion

Use of mobile health technology for empowerment of patients with diabetes is an emerging way to improve their health and wellbeing. It can address almost every problem of diabetic patient. But approaches are diverse and every app has its own properties and functionalities. There are many apps on the market, but only few of them are adequately certified by health care authorities. Therefore, their quality is questionable. But many studies showed, mHealth is effective and even cost-effective, though more research is needed.

The future applications should be more personally oriented, improved regarding usability and accessibility, and based on accepted clinical guidelines.

Author details

Matjaž Krošel[1], Lana Švegl[1], Luka Vidmar[2] and Dejan Dinevski[1*]

*Address all correspondence to: dejan.dinevski@uni-mb.si

1 Faculty of Medicine, University of Maribor, Maribor, Slovenia

2 Telekom Slovenije d.d., Ljubljana, Slovenia

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