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MOBILE & WIRELESS HEALTH

Mobile Applications for Control and Self Management of Diabetes: A Systematic Review

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Abstract Mobile applications (apps) can be very useful software on smartphones for all aspects of people's lives. Chronic diseases, such as diabetes, can be made manageable with the support of mobile apps. Applications on smartphones can also help people with diabetes to control their fitness and health. A systematic review of free apps in the English language for smartphones in three of the most popular mobile app stores: Google Play (Android), App Store (iOS) and Windows Phone Store, was performed from November to December 2015. The review of freely available mobile apps for self-management of diabetes was conducted based on the criteria for promoting diabetes self-management as defined by Goyal and Cafazzo (monitoring blood glucose level and medication, nutrition, physical exercise and body weight). The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) was followed. Three independent experts in the field of healthcare-related mobile apps were included in the assessment for eligibility and testing phase. We tested and evaluated 65 apps (21 from Google Play Store, 31 from App Store and 13 from Windows Phone Store). Fifty-six of these apps did not meet even minimal requirements or did not work properly. While a wide selection of mobile applications is available for self-management of diabetes, current results show that there are only nine (5 from Google Play Store, 3 from App Store and 1 from Windows Phone Store) out of 65 reviewed mobile apps that can be versatile and useful for successful self-management of diabetes based on selection criteria. The levels of inclusion of features based on selection criteria in selected mobile apps can be very different. The results of the study can be used as a basis to prvide app developers with certain recommendations. There is a need for mobile apps for self-management of diabetes with more features in order to increase the number of long-term users and thus influence better self-management of the disease.

Keywords Mobile apps · Self-management of diabetes · Health

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Introduction

Accoding to the latest report (September 2015) from the IMS Institute for Healthcare Informatics the number of mobile health (mHealth) applications (apps) available to consumers exceeded 165,000 and since 2013 there has been progress in understanding and addressing the barriers to more mainstream adoption of mHealth. The majority of available mHealth apps are concentrated in the areas of wellness, diet and exercise. Nearly a quarter of mHealth apps focus on disease and treatment management, reflecting the growing interest in the use of mHealth apps for chronic disease management [1].

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According to the recent study by Bhuyan et al. [2] about the use of mobile health applications (mHealth apps) for health-seeking behaviour, using the data gathered in 2014 with the Health Information National Trends Survey (HINTS 4), 36 % of adults possessing smartphones or tablets had mHealth apps on their devices. Among those with apps, 60 % reported the usefulness of mHealth apps in achieving health behavior goals, 35 % reported their helpfulness for medical care decision-making, and 38 % reported their usefulness in asking their physicians new questions or seeking a second opinion.

Dennison et al. [3] conducted a qualitative study in young adults with the objective to explore their experiences and views on apps related to health behavior change, including their perceiving of various features and their willingness to use these apps. The findings suggested that people are interested in using apps that support health behavior change. They identified several valuable features that have important influences on the app usage such as: accuracy, legitimacy, security, effort required and immediate effects. It is interesting that context-sensing capabilities and social media features were considered unnecessary. Nevertheless, they have also noted that some participants in their study were not motivated enough to regularly and precisely use the apps in making healthy lifestyle changes.

The World Health Organization estimates that the global prevalence of diabetes in 2014 was 9 % among adults aged 18 and over [4]. This is a worrying fact and professionals should be focusing on aims that stimulate effective measures for surveillance and prevention.

There are already many mobile apps on the market for assisting people with diabetes. Together with the effectiveness of telemedicine and the health system, patients can overcome geographical barriers and be provided with frequent follow-up and feedback. However, there are still some controversial perspectives in the role of mobile apps for self-managing diabetes. According to El-Gayar [5] "there is a distinct need to employ a user-centered design that will take into account the needs and characteristics of the individual patient". The problem lies in the inability of most apps to differentiate between type 1 diabetes and type 2 diabetes. As a result, the app works the same in both cases, leaving aside the fact that these two conditions may need different medication plans (oral medications, insulin pump, insulin injections), nutritional intake and physical exercises [6].

Another issue is related to the substantive side of apps. Goyal and Cafazzo [7] claim in their report on mobile health apps for diabetes management that only 20 % of apps assessed had an educational component that helps people with diabetes to be more motivated about making crucial life changes. Without embedded behaviour strategies, mobile apps are at risk of becoming just a substitute for paper from which patients gain no additional knowledge [7]. Still, there are some consensuses that these patients could benefit from managing diabetes and their lifestyle behaviour with mobile apps. El-Gayar et al. [5] highlight that the use of these apps improves healthy habits, for instance following a healthy diet, increasing physical activity and increasing blood sugar testing. This last is especially important for patients who have very high blood sugar levels and are having difficulty in controlling them. Another aspect that they have reported is related to patients with prediabetes. Their blood glucose level is higher than normal but not yet high enough to be diagnosed as diabetes. Therefore, they need support and guidance to a better lifestyle, which can be enabled by using mobile apps.

Additionaly, some concerns about privacy, accuracy and safety have to be raised. This means that we do not know what companies do with the data entered into such apps. The US Food and Drug Administration claims that apps can be called medically regulated devices when they provide patients' results, diagnosis, or treatment recommendations that are used for making clinical decisions. Many apps in stores are defined as medical, though this was not provided by medical experts. Therefore some users can incorrectly assume that this label automatically means medical effectiveness [8]. It is also important to take special care of the collection and treatment of users' personal health information saved in mobile apps and to consider secure transfer of the data [9–10].

Another problem with the use of mobile apps concerns people who are not acquainted with the use of smartphones or they are low in health literacy. Because of this they are less likely to access and use health technology [11].

The aims of this study were: (1) To identify how many of the freely available mobile apps for people with diabetes provide the support for basic features for successful self-management of diabetes proposed by Goyal and Cafazzo [7]; monitoring blood glucose level, monitoring insulin dosage and/or other medications, nutrition, physical exercise and monitoring body weight; (2) To review in what degree are the selected features implemented in the identified mobile apps for self-management of diabetes.

The search for the mobile apps was limited to the three most frequently used mobile app stores (Google Play, Windows Phone and iOS Store). As cost free availability of mobile apps is considered as one of the valuable features of health behavior apps [3], we decided to focus only on freely available mobile apps.

Methods

The review of mobile apps for support in self-management of diabetes was conducted following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) proposed by Moher et al. [12].

For the final display we used the PRISMA flow diagram, which shows the course of information through the different phases of a systematic review. Through this stage of the review we also compared our individual results of reviewed apps.

Research Questions

The objective of this study is to answer the research questions (RQ) presented in Table 1.

Inclusion Criteria

The free availability and English language of mobile apps were basic inclusion criteria. All apps had to support all basic self-management tasks considered in Goyal and Cafazzo [7] and Goyal, et al. [13] monitoring blood glucose level, insulin dosage and/or other medications, nutrition, physical exercise and body weight. The same self-management tasks are also surveyed by Chomutare et al. [14] as basic self-monitoring features. Apps were excluded if the installation process was not successful or the app did not work properly.

Search Strategy

The PICO criteria were used to define the search string: population (P), intervention (I), comparison (C) and outcome (O) [15]. The population considered was diabetic patients; the intervention was free mobile apps for self-management of diabetes; the comparison part was excluded; outcomes were all existing mobile apps for self-management of diabetes. As the search results should have the maximum possible coverage, the search string was defined as "diabetes" according to the aims of the study.

Three mobile app stores were used: Google Play Store (Android), App Store (iOS) and Windows Phone Store (Windows). The selected mobile stores were chosen based on popularity and market share. In the first quarter of 2015 Android still dominated the market with a 78.0 % share. iOS did not nearly reach these percentages and had a share of 18.3 %. Windows Phone had the smallest year-on-year increase in 2014 among the leading operating systems. Because of this, market share was only 2.7 % for the first quarter of 2015 [16].

The review was conducted from 12 November to 30 December 2015.

Selection Process

All potentially relevant mobile apps by title and description were independently screened for eligibility by three experts (PPB, PK, ER) in the field of healthcare-related mobile apps. The subjective assesment of a mobile app's features by each reviewer introduces a source of bias to this study. In the attempt to mitigate this bias, we required that at least two reviewers agree with the inclusion of the app into the further analysis. Differences in judgement were resolved through a consensus process. The inter-rater agreement based on Cohen's Kappa statistic between the reviewers ranged between 0.77 (reviewer 1 vs. reviewer 3) and 0.90 (reviewer 2 vs. reviewer 3).

The evaluation of mobile apps features included five main categories (personal data, glucose and insulin therapy, nutrition, physical activity and additional features) with subcategories. A template containing the data that should be extracted was designed in the form of a Excel spreadsheet, which is further presented in Table 3. Each application was independently assessed by all three reviewers. The Cohen's Kappa coefficient ranged between 0.88 (reviewer 1 vs. reviewer 3) and 0.94 (reviewer 2 vs. reviewer 3), which indicates a high level of agreement.

Results

Search Results

The initial search by the search term "diabetes" that resulted in 956 mobile apps (Google Play 250, App Store 500, Windows Phone Store 206) identified was followed by manual inspection of the app's title and description where accessible. Several mobile apps found on the first step were not intended for self-management of the disease and for example included only the description of the disease, medical information, the description of the diet, recipes for diabetic patients, possible treatments, complications, magazines, fitness apps, etc. The apps that did not meet the inclusion criteria were excluded. After independent judgement by three reviewers, 34 apps in Google

Table 1 Research questions

ID	Research Question	Motivation
RQ1	Which of the freely available mobile apps for people with diabetes provide the support for basic features for successful self-management of diabetes (monitoring blood glucose level, monitoring insulin dosage and/or other medications, nutrition, physical exercise and monitoring body weight) are available in app stores (Google Play Store, App Store and Windows Phone Store)?	To identify the mobile apps for self-management of diabetes that are freely available in the English language and support for basic features for successful self-management of diabetes. To identify which app store offers most mobile apps for self-management of diabetes.
RQ2	What are the caracteristics of the identified mobile apps for self-management of diabetes?	To analyze which features are presented in identified mobile apps and to what degree.

Play Store, 40 apps in App Store and 26 apps in Windows Phone Store were considered for further testing. In the next step a further 34 apps (Google Play 13, App Store 9, Windows Phone Store 13) were excluded because of installation, functionality failure or restrictions in free use. The remaining apps (21 from Google Play Store, 31 from App Store and 13 from Windows Phone Store) were successfully installed and independently tested by all reviewers. The majority of apps did not meet even minimal requirements, namely the glucose and insulin entry and tracking or did not work properly. Specifically, in 24 apps only saving and tracking of measurement of blood glucose level was enabled. Two additional apps had also the possibility of saving and tracking of medications (insulin type and dosage). They were therefore excluded from further review. The tracking of nutrition was supported in 36 of the remaining 39 apps. Only 13 applications (5 from Google Play, 7 from App Store and 1 from Windows Phone Store) included the possibility to save and track personal body weight or body mass index (BMI). Four additional apps from App Store did not support tracking physical exercise and were consequently excluded from further analysis. The final search yielded nine apps that corresponded to all inclusion criteria. The process of elimination described above is presented with the PRISMA flow for each mobile store separately (Fig. 1).

Description of Mobile Apps

This section describes the characteristics of nine mobile apps that were identified in the systematic review. Basic information about these apps and their short names used are presented in Table 2.

The apps A3 and A5 are available for Android and iOS users. All apps except I2 are intended for use with both types of diabetes, but I2 is limited only for users with type 2 diabetes. All reviewed apps (except I1) have the option of entering basic personal user data such as name, sex, and age. The apps are described by the features connected to inclusion criteria (Table 3). The inclusion criteria are described in further subsections as implemented in reviewed applications.

Management of Blood Glucose and Medication

None of the reviewed apps has the possibility to use mobile glucometers that can be plugged directly into the smartphone's headphone jack and display results instantly on the phone screen. When using app A1, the data from various independent glucometers and insulin pumps can be imported by Bluetooth or Wi-Fi and analyzed. Additionally, to the calculation of the average daily/weekly/monthly blood sugar levels, apps A3, A4 and I3 include the possibility to store the results of A1C tests, which calculate the average blood sugar level for the past two to three months on the basis of percentage of glycated haemoglobin in blood.

App A1 also includes automated bolus calculator (ABC) for calculating meal insulin boluses. The ABCs can be used to assist with pre-meal insulin dosing for patients using insulin with or without pumps and have been proven to be effective in managing glucose levels and preventing hypoglycaemia. The ABCs base the calculations on the target blood glucose level, the current glucose level, the carbohydrate-to-insulin ratio, total carbohydrates for that one meal and the insulin sensitivity factor.

Fig. 1 PRISMA flow diagram for diabetes self-management mobile applications found in three most popular mobile stores (Google Play, App Store and Windows Phone Store)

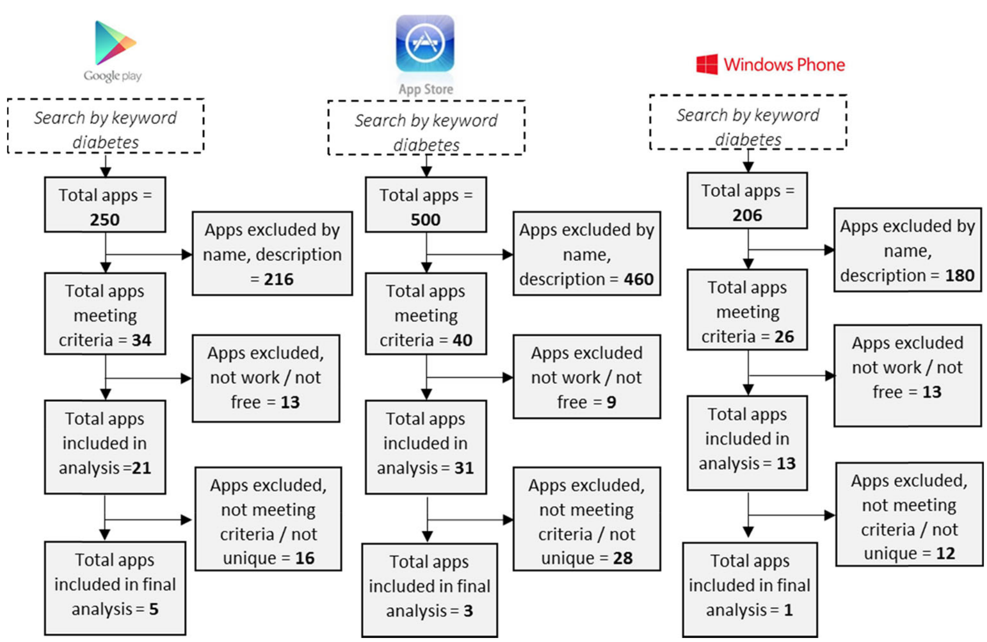

Table 2 Basic information on reviewed apps

Apps name	Short Name *	Store	Developer Name	URL shortener
Diabetes: M	A1	Google Play	Rossen Varbanov	http://goo.gl/QcEVNa
Diabetes Tracker	A2	Google Play	Mig Super	http://goo.gl/Fp8Sol
Glucose Buddy: Diabetes Log	A3	Google Play	Azumio, Inc.	http://goo.gl/sJM6FV
Diabetes Journal	A4	Google Play	Suderman Solutions	http://goo.gl/7zy0ih
Diabetes Connect	A5	Google Play	Square Med Software	https://goo.gl/uBa5Ds
Diabetes App Lite	I1	App Store	BHI Technologies, Inc.	https://goo.gl/80dHcY
Diabetes in check	I2	App Store	Everyday Health, Inc.	https://goo.gl/ADmsCN
Carburetor - Diabetes Logbook Manager	I3	App Store	Vortec, Inc.	https://goo.gl/gospXp
dbees.com	W1	Windows Phone Store	Freshware	http://goo.gl/0euz6H

* Short name code refers to the mobile operating system: A = Android, I = iOS, W = Windows

We found that seven (A1, A2, A3, A4, A5, I1 and W1) out of nine apps enable graphical display of blood sugar levels. In app I3 the measured blood sugar levels can be seen only in the tabular display. All reviewed apps except I3 allow sharing gathered data of measured blood sugar levels as some kind of exported file that can be printed or sent to any persons of interest. Sharing/exporting the data can be quite useful, especially for people who want to keep track of blood sugar levels for a longer period of time or want to use them in their consultations with the physician.

Four applications (A1, A3, I2 and W1) support the setting of reminders for glucose measurement and/or medication intake, which aims to improve diabetic patients' daily routine. Additionally, apps A2 and A5 offer the use of reminders for an additional charge.

Nutrition

The number of meals indicator is mostly optional and units are in grams. Apps A1, A2, I1, I2 and I3 take into account the

Table 3 Description of supported features by inclusion criteria in reviewed mobile apps for self-management of diabetes

	Feature/App	A1	A2	A3	A4	A5	I1	I2	I3	W1
	Personal data	x	x	x	x	x		x	x	x
	Diabetes type	T1/T2	T1/T2	T1/T2	T1/T2	T1/T2	T1/T2	T2	T1/T2	T1/T2
Glucose & Insulin Therapy	A1C test			x	x				x	
	ABC calculator	x								
	Tabular display of blood sugar levels	x	x	x	x	x	x		x	x
	Graphic display of blood sugar levels	x	x	x	x	x	x			x
	Share/Export data	x	x	x	x	x	x	x		x
	Reminders	x	x*	x		x*		x		x
Nutrition	Food database with calories	x	x						x	
	Calories intake	x					x	x	x	
	Carbohydrates intake	x			x	x	x	x	x	x
	Fluid intake						x			
	Average time for meal log in minutes	5	2	2	1	2	1	1	1	<1
Physical Activity	Calories burned							x		
	Reminders		x*	x		x*		x		x
Additional Features	Education about diabetes		x	x				x		
	Forums/Community			x		x		x		x
	Blood pressure	x	x	x	x	x				
	Pulse					x				
	Notes		x			x			x	
	Support for smart watch	x								

T1 = diabetes type 1; T2 = diabetes type 2

* Only for premium users (additional fees)

calories gained with meals. All apps except A2 and A3 allow the input of carbohydrate intake for each meal. The interesting simplification of the meal input can be seen in A1 where the user can also measure the size of the food intake with cups/pieces/glasses. Similarly, in app W1 users can choose among different sizes of the meal (small/medium/large). App A1 is also the only app with the support for voice recognition for selecting food from a food database. The uniqueness of app A2 is the possibility to use proposed easy to make and tasty recipes along with diet guidelines for the various types of diabetes and superfoods that will help users to keep the glucose on normal levels. App I1 includes a library of various types of food used in different meals and their calories, protein, fibres, sugar, cholesterol, etc. The users choose the type of food and the units. This app (I1) is also the only one of those reviewed that allows tracking fluid intake. An original and useful idea is the barcode scanner within app I2, which allows users to quickly track the carb and nutrition facts for all packaged foods and includes a quick reference guide of what to eat with various recipes. App I3 also includes a food database with calories and carbohydrates. Additionally, users have the possibility of adding their own custom foods.

Physical Exercise

Users of the mobile apps usually have an option to enter or to select a specific physical exercise. In connection with this they need to enter duration and sometimes also intensity of the exercise. Only one app (I2) has an option to calculate the calories burned during the exercise. App I2 also suggests some physical exercise to burn excess calories. Three apps (A3, I2 and W1) include reminders for physical activity, which can be set by users. Apps A2 and A5 offer the use of reminders, however, only as a paying option for premium users.

Monitoring Body Weight

All mobile apps include the input of body height and weight, however four apps (A1, A2, I1, W1) have an additional opption to calculate BMI. The continuous monitoring of body weight is possible in all selected apps. All apps support the input in metric units.

Discussion

This section discusses the results and the main findings of this study. Recommendations for developers of mobile apps for self-management of diabetes are also proposed.

RQ1: Which of the freely available mobile apps for people with diabetes provide the support for basic features for successful self-management of diabetes (monitoring blood glucose level, monitoring insulin dosage and/or other medications, nutrition, physical exercise and monitoring body weight) are available in app stores (Google Play Store, App Store and Windows Phone Store)?

According to Chomutare et al. [14] a mobile app for self-managing diabetes should support insulin and medication management, diet, physical activity, weight, blood pressure, education, social media, alerts, communication and monitoring of patient by primary care providers. In this review basic key features (monitoring blood glucose level and medication, nutrition, physical exercise and body weight) as proposed by Goyal and Cafazzo [7] were selected as inclusion criteria. The results show that most of the free apps for self-management of diabetes available in selected mobile stores provide only some of the basic features that are required for proper self-management of diabetes. Only nine multifunctional free mobile apps that support tracking of blood glucose level, insulin type and dosage, monitoring of nutrition, physical exercise and body weight, were identified (Table 2). Five of the identified nine apps can be found in Google Play Store and two of them (A3 and A5) are also available in App Store. In App Store we identified three additional apps and in Windows Phone Store only one.

RQ2: What are the caracteristics of the identified mobile apps for self-management of diabetes?

All identified mobile apps include basic self-management features that are presented in the results section (Table 3). All apps except one (I2) support both types of diabetes. However, 90–95 % of people have type 2 diabetes and most of them do not measure blood glucose level on a daily basis and also do not use insulin, but oral medication, diet and regular physical activity [17–19]. Based on different needs of people with diabetes type 1 and type 2, it would be reasonable to adapt the functionalities of the mobile app to the needs of patients with a specific type of diabetes.

Hypoglycaemia presents a considerable problem with diabetic patients on insulin therapy. Use of ABCs in glucose monitors and smartphone applications [20] or other calculators for insulin dosage [21] have the potential to improve glucose control in a larger population of individuals with diabetes on insulin therapy by overcoming the fear of hypoglycaemia and assisting the patients with low numeracy skills. Among the reviewed mobile apps only one includes the use of a ABC calculator, although seven apps use carbohydrate intake, four apps include calories intake and three apps use a food database with information about calories, proteins, fibres, etc.

The American Diabetes Association states that regular physical activity is important for maintaining health and fitness for people diagnosed with diabetes. They are advised to participate in at least 150 min of moderate-intensity physical activity per week. Regular exercise has been shown to improve blood glucose control, reduce cardiovascular risk factors, contribute to weight loss and improve well-being [22]. However, only one of the reviewed mobile apps (I2) supports also the calculation of burned calories during physical activities although all newer smartphones are equipped with accelerometer, gyroscope and pedometer, which can be used to track the users' physical activity automatically also in mobile apps for self-management of diabetes. None of the reviewed apps includes pedometer and/or accelerometer in order to track physical activity and calculate burned calories. Some apps (A1, A2, A3, A4 and A5) support entering and storing blood pressure levels and only one app (A5) also supports storing measured heart rate.

Most diabetic patients still use the paper-based methods to track their blood glucose level and related factors. They bring the collected notes to their physician appointment in order to show the success of the management of their diabetes. During this review we noted that almost all selected apps support sharing and/or exporting the collected data with the physician. Additionally, four of the selected apps (A3, A5, I2 and W1) include the possibility to connect and share experiences with other people through forums or different communities and social networks. The inclusion of social media can be very supportive in self-management of diabetes [14].

The data sharing is also important for supervision of blood glucose monitoring and regulation in children with diabetes and elderly patients by their parents or guardians. The short message service (SMS) can be used to automatically alert the parents/guardians of high/low levels of blood glucose, irregular insulin dosages and dietary and dosage advices [23].

We were very surprised by the fact that only three (A2, A3 and I2) out of nine apps include also educational material about diabetes. Education about diabetes may be helpful for promoting motivation and engagement in behavior change [24].

The same three apps (A2, A3 and I2) offer the user also the hints and tips for using the app. As Skrovseth et al. [25] experienced, the most common reason for quitting the use of mobile apps is connected with the difficulties to use the smartphone. For that reason, these authors suggest that for all apps a significant amount of training for patients is necessary. The expectations that patients immediately understand the implemented ideas are not justified. The face-to-face training for the self-management of diabetes is necessary when the patient is firstly diagnosed with diabetes and at the therapy modification. In our opinion this training should include also the training for the use of the chosen mobile app. However, in general each mobile app should offer also a tutorials for the use.

The next common reason for abandoning or not using apps regularly is also the need of time for entering the data. For example, we measured the average time users need to enter all information about a meal. We entered the same three basic meals in all apps for fair comparison. The average time spent for the entry of one meal ranges between one and two minutes, except for app A1 where we spent on average five minutes to enter the meal data. Entering at least five meals per day, one or more measured blood glucose levels and insulin intake and possible physical exercise, can be very time consuming. The app developers should therefore consider possible solutions to make this process less complicated. For example, the app A1 supports entering the meal using voice recognition, which can be very useful, but mainly for fluent English speakers. A very good solution can be the use of a barcode scanner with the connection to the database of calories, carbohydrates, proteins, sugar, etc. for packed food. However, this is limited to the use on already prepared food and should be used in combination with food recipes. This idea is implemented in only one of the reviewed apps (I2).

The influence of stress on blood glucose levels is well recognized. The American Diabetes Association claims that most sources of stress are related to mental health. Stress hormones can be activated for long periods of time resulting in long-term stress. Over the years this leads to elevated blood sugar levels. There are also different effects of mental stress on people with type 1 and type 2 diabetes. People with type 1 diabetes may have reduced blood sugar levels while experiencing mental stress. On the contrary, people with type 2 diabetes have usually raised blood sugar levels during mental stress. With physical stress, such as illness, there is no difference between the diabetes types; however, the influence can be recognized in increased blood sugar levels [26]. Only one app (I3) supports input of stress elements connected to well-being.

The additional benefit for users can also be the inclusion of notes in the daily data input. Notes can be used for daily activities, physical and psychological well-being during the day, experiences, additional medications, etc. Apps A2, A5 and I3 support written notes; however app I3 is limited to a maximum of 60 notes for free users. The app A2 supports also calculation of all expenses for diabetic treatment on the basis of input notes.

Smartwatches have been on the market since the 1980s [27]. A smartwatch is a computerized wristwatch that can connect to the smart phone and exploit its functionalities. The most important advantages of using a smartwatch are its discretion, the possibility to quickly look at the messages and also fast entering of the data. Arsand et al. [28] demonstrated the new possibilities within the diabetes self-management field that were opened up by the use of smartwatches, such as easier ways of monitoring blood glucose, insulin dosage, physical activity and dietary information directly from the wrist. They presented the development of a Diabetes Diary app for the Pebble smartwatch. The only diabetes self-management app in this review that communicates between a smartwatch and smartphone is A1. The use of smartwatch in app A1 is very simple. The smartwatch app supports voice recognition for entering notes, measures blood glucose level in mmol/l, carbohydrates in grams, calculation of meal insulin boluses using the ABC calculator, displaying the sum of daily insulin boluses already applied in units and entering applied insulin boluses with the information about the time of application or blood glucose measurement. All data entered via smartwatch is saved to general apps on a smartphone. Although smartwatch technology is still in its infancy it can make it easier for people with diabetes to self-manage their disease.

Several studies [2, 29–32] about the effectiveness of the use of mobile apps for self management of diabetes have already been published. The conclusions differ mostly due to high variability of studies, methodological weaknesses, unsufficient sample size and/or duration of the study [33, 34].

Recomendations for Apps Developers

Based on the results of this review, we encourage the developers of apps for self-management of diabetes to:

- Develop different versions of apps for each diabetes type.
- Include medical experts in the development of apps.
- Enable at least basic self-management tasks, such as monitoring blood glucose level, monitoring insulin dosage and/or other medications, nutrition, physical exercise and monitoring body weight.
- Enable easy data entry (voice recognition, image recegnition, data transfer from other devices, built-in smartphone sensors).
- Enable analysis of the data and the patterns in the gathered data in order to observe the interactions between blood glucose level, food intake and physical activity.
- Include prediction of blood glucose level based on gathered data.
- Enable the compatibility with different operating systems for smartphones by using packages that are available for different platforms.
- Enable saving data transfer and sharing (from external devices, diabetic patient to medical expert, between family members (child/parents, elderly pearson/guardian, etc.)).
- Consider the possibility to connect the apps with the patient electronic health record (EHR).
- Include motivational features for health behavior change (forums, social networks, reminders, alerts, etc.)
- Include the up-to date educational material about diabetes.
- Include the tips for better self-management of specific type of diabetes.
- Include the tutorial for using the app.

Limitations

Several key limitations of the current study have to be emphasized. First, only three reviewers were included in the study and therefore the observations and recommendations presented in this paper are based only on their experiences. The reviewers were experts in the field of healthcare-related mobile apps and therefore their opinion is based only on the hypothetical app use and does not reflect the opinion of the actual users of these apps. In order to get the relevant opinion on the usefulness of the apps for self-management of diabetes, further research should include people with diabetes who would use the apps for a longer time period.

Second, there is a risk of possible incompleteness of the data as only three app stores were searched. Some apps can also be downloaded from the web pages of the hospitals, the developer's web pages, etc.

A limitation of the study is also our inclusion criteria in which we restricted the search only to freely available apps. The number of selected apps without this limitation would be higher and in many cases the apps would have more available features. Similarly, the inclusion of apps available in English can also present a limitation of this study. Nevertheless, we believe that our findings can be used in future works on diabetes apps.

Conclusion

A main finding from this review is that only nine freely available apps for self-management of diabetes for Android, iOS and Windows phones include all four basic features recommended by clinical guidance, i.e. tracking of blood glucose, insulin therapy, nutrition and physical activity. However, the levels of inclusion of these features can be very different. Based on the different needs of people with type 1 or type 2 diabetes, the mobile apps should be customized to the specific type of diabetes.

In order to predict correctly the blood glucose level and thus accurately calculate the insulin dosage needed, the information about nutrition and physical activity is a necessity. We noticed the lack of entered information about nutrition that is important for prediction of blood glucose and thus calculation of needed insulin dosage. Most of the apps only allow entry of the information about the type and the time of physical exercise, but not the strength. It would be more effective if the app would take advantage of the smartphone's built-in sensors (such as accelerometer, gyroscope and Global Positioning System (GPS)) to collect all information about physical activity to calculate the calories burned.

In our opinion the users of apps for self-management of diabetes would also benefit from all kinds of reminders (such as reminders for measuring blood glucose, insulin therapy, meals and physical activity) and notes for tracking physical and psychological well-being. For example, studies have already shown that even a SMS service results in better medication adherence [23, 35, 36].

The next main finding is that education in the use of apps is not assimilated in most of the apps and the lack of education can discourage users from continuing with the use of apps. Education for and about the self-management of diabetes can also be a part of apps as encouragement for users to use them properly and continuously. Similar findings have also been outlined by Shah and Garg [37] where the use of newer technologies and digital health in diabetes self-management were assessed. Additionaly to already mentioned features that should be supported by apps for self-management of diabetes, the authors outline also the communication with health care professionals and the possibility to connect the apps with the patient EHR, which has already showed positive effect in reduced primary care office visits and telephone contacts [38].

Since the beginning of the development of smartphones, mobile apps have expanded and allowed increasing numbers of possibilities for use. However, there still remains a great deal of room for improvement and research.

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