Original Article

Advancing Diabetes Self-Management: A Novel Smartphone Application Featuring a Scoring Algorithm for Tailored User Engagement

Mohammad A. Tebianian, Soodeh Razeghi Jahromi[1]

Department of Computer Software Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran, [1]Department of Clinical Nutrition, School of Nutrition Sciences and Food Technology, Shahid Beheshti University of Medical Sciences, Iran

Abstract

Background: We developed and evaluated an intelligent diabetes assistant application (Diabetter) for the self-management of diabetes. It suggested that increasing the patient's interest and participation in using smartphone apps is important for the effectiveness of diabetes management apps. **Methods:** After evaluating all-encompassing features for diabetes management, we divided the selected factors into sub-factors for use in the application. Then, we created the first high-fidelity prototype using related programs and conducted early user testing to validate and improve Diabetter. To handle the user transaction time and keep them motivated, we designed and implemented a scoring system based on the nudge theory rules within the app. **Results:** To evaluate Diabetter's impact on diabetes self-management, we measured HbA1c levels after a prolonged period. The Diabetter prototype was developed and modified in a revised version for better user interaction with the app. The scoring system increased the input of users' information, which resulted in more analysis and recommendations to users. Clinical studies showed that as a result of continuous input of information from users who had been using the application for a longer period of time, their HbA1c levels were within the healthy range. **Conclusions:** The results demonstrate that the Diabetter application has been able to play an effective role in diabetes self-management by increasing users' app usage time. However, future study is needed to provide a better interpretation.

Keywords: *Diabetes, HbA1c, mobile application, self-management*

Introduction

Diabetes is a chronic complex disease characterized by elevated levels of blood glucose. This disease, which is divided into types I and II, results either when the pancreas does not produce enough insulin or when the body cannot effectively use the insulin it produces, respectively.[1,2]

Unfortunately, in recent years, the prevalence of both types of diabetes has increased significantly around the world, which can be attributed to infectious or non-infectious factors and unhealthy lifestyles.[3]

According to the International Diabetes Association data, in 2019, 463 million of the world's adult population suffered from diabetes, and it has been estimated that will reach 700 million (10.9%) in 2045.[4] In addition to improving the patient's general health, self-management strategies will reduce treatment costs and improve the patient's relationship with healthcare systems.[5,6] These include tracking blood glucose levels, adhering to medication or insulin therapy, and measures of physical activity and dietary habits.[7,8] For this purpose and to continue monitoring these factors, smart mobile applications could be considered as a practical and attractive option that has been used in this disease.[9-11]

In recent years, several smartphone applications have been developed for diabetic persons to increase their quality of life and improve their disease outcomes.[12-16]

Most of these apps are aimed to monitor blood glucose, weight range, and so on. However, persons with diabetes need more support as they involve many daily complex behaviors and individual medical decisions.[17-19] Considering that people with diabetes have to make decisions more often than non-diabetics, and this is boring and time-consuming, there should be a tool to help them monitor diabetes measures.

The aim of this study was the development of a comprehensive smartphone application with a scoring system for the improvement

How to cite this article: Tebianian MA, Jahromi SR. Advancing diabetes self-management: A novel smartphone application featuring a scoring algorithm for tailored user engagement. Int J Prev Med 2024;15:20.

Address for correspondence:
Dr. Mohammad A. Tebianian, Department of Computer Software Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran.
E-mail: tebianianmohammad amin@gmail.com

Access this article online

Website: www.ijpvmjournal.net/www.ijpm.ir

DOI: 10.4103/ijpvm.ijpvm_268_23

Quick Response Code:

of self-management in persons with diabetes. It is expected that the scoring system could improve the quality of life and will be effective in monitoring the treatment process in diabetic persons.

Methods

Data collection and study design

The essential features and information were collected and identified by a specialist clinical and medical team. These factors were evaluated by field studies and library resources. Four basic principles for diabetes control were considered in this system: 1- control of blood glucose level, 2- medication regimen, 3- nutritional elements, and 4- physical activity. The selected factors were divided into subcategories to evaluate more accurately. In this case, to calculate users' foods and nutrition points, proper calculations were done using optimized formulas based on the USDA healthy eating index, which was collected from users and clinical studies. In addition to the previous four principles, two other factors were considered in designing and implementing the scoring system: medication and control of blood sugar. All of the scores of this part are based on American Diabetes Association (ADA) guidelines, and the scoring system adapts itself to the newly updated guidelines. For example, if a user injects the appropriate dose of insulin, which causes the blood glucose level to be in the healthy range (based on the ADA guidelines) after eating, it will take most of the scores of medication for that specific meal.

Application design and development

After considering all factors, the initial version of the intelligent diabetes assistant application (iDia) was described and programmed in the Android Studio programming environment. The primary user interface was developed on Adobe XD and upgraded based on user feedback. The Agile mechanism was used for application development. To achieve this, the Kanban framework was used in conjunction with regular scrum and sprint sessions. During these tests, each of the server-side APIs, both individually and in combination, is subjected to multiple calls, and the response time status of the user is measured and evaluated. Information received from patients was stored in related databases and tables. This portal prevents unauthorized access to patient information through secure protocols. After further investigation, an optimized version of the application was developed using the *Dart* Programming language (Flutter) to make it a single-source program. In the updated version of iDia (named Diabetter), all the features required for easy access by users were placed on the main menu [Table 1]. In addition, the notifications are intended to help users make the best decisions to control diabetes in critical moments. For example, when the blood glucose level is high, the application alerts and offers that it is better to take the recommended dose of insulin before eating. As a unique feature, in addition to announcing the current condition, the application alerts the user about any risk caused by incorrect decisions. For example, if a user wants to inject more doses of initial insulin, they are warned that they have already injected insulin and that there may still be some of it in the body.

Clinical evaluation

The usability and user satisfaction of the application were evaluated by qualified participants. This procedure was conducted in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The protocol was guided by the Ethics Committee of *Shahid Beheshti University of Medical Sciences*. All participants provided informed consent prior to their inclusion in the study

5200 subjects with type 1 diabetes and 4500 with type 2 diabetes were included in the study. All of the participants were randomly selected, and the Diabetter application was installed on their smartphones. After training, they were asked to record their demographic data, including height and weight, age, and gender, as well as average glycosylated hemoglobin levels (HbA1c) and treatment protocols.

The effects and usability of Diabetter on self-care status were assessed using a controlled protocol during a 6-month period. Inclusion criteria included patients in the age range of 12–18 years with type 1 diabetes (according to the American Diabetes Association guidelines), who had been diagnosed for at least 1 year. In addition to not suffering from debilitating complications of diabetes such as kidney failure and blindness, all studied patients should have the ability to communicate and use mobile phones. Exclusion criteria were having type 2 diabetes or secondary diabetes and children who did not have enough follow-up skills. All patients included in the study were randomly divided into two groups. The participants in the test group had the Diabetter application installed on their smartphones. After training, they were asked to record their demographic data, including height and weight, age, and gender, as well as an average of glycosylated hemoglobin levels (HbA1c) and treatment protocols. Considering that the biosynthesis and glycosylation process of hemoglobin A1C is carried out over a relatively long period of 60–120 days, the duration of the study was considered to be 6 months. Hemoglobin A1C was measured and evaluated at the beginning and end of the study for all patients in the control and test groups. At the end of the study and for qualitative evaluation, the patients were classified as follows: good control: A1C $\leq$ 7.5, moderate control: 7.5 $\leq$ A1C $\leq$ 9.9, and poor control: A1C $\leq$ 10.

Statistical analysis

Statistical analysis was performed using SPSS version 21 software, and the results were compared and evaluated using Chi-square, independent *t*-test, and paired *t*-test.

Table 1: List of features incorporated into the Diabetter application

Features	What it does	Reason
Total Diabetter point	Give points to each user's behaviors and interactions with the application.	Help app users with diabetes understand and manage their condition effectively by using behavioral nudges to overcome biases for better daily control
Diabetter point in detail (blood sugar, insulin/medication, exercise, food, emotions, behaviors)	Informs users of the points awarded in various scenarios	Improve user understanding of diabetes management by highlighting areas needing enhancement, enabling informed actions for better control.
Lead board	Leaderboard displaying daily top diabetes management among Diabetter app users	Research shows comparing with others increases attention, guiding our user engagement strategy
Add/Track Blood Sugar	Recording of blood sugar for each meal; users can later review daily trends via graphs and lists	It is necessary for a diabetic person to record their blood sugar.
Blood Sugar Alert	Inform users of their blood glucose levels, advising caution and awareness if readings are in the hypo or hyper range to guide their decisions	Diabetics must track glucose levels. The app alerts to critical values without causing stress, prompting corrective measures
Add Insulin	Log insulin doses per meal in the app to monitor daily intake and track the remaining effect of short-acting insulin, which typically lasts two hours, as per the American Diabetes Association	Diabetter alerts users to recent insulin injections, emphasizing the importance of consistent logging and caution to prevent blood sugar drops from dosage overlap
Insulin Suggestion (This is only a suggestion and does not force the user to inject that amount of insulin or so.)	Diabetter recommends insulin dosages for diabetic patients based on carbohydrate consumption and past injections, with an editable option for personal adjustment. Note: This applies to short-acting insulin, typically for type Type 2 diabetics managing mealtime injections	Our app aids diabetics in insulin dosage decisions by providing suggestions based on a detailed food database for precise carbohydrate calculation and meal-specific insulin requirements
Add Food/Track Food	Users can choose their meals from our food database to view nutritional content, including carbohydrates, to determine the insulin needed for that meal. They can also track their daily food intake by saving the meal information	Diabetter enables diabetic patients to select meals from a vast food database, assess nutritional details, and understand the physical activities needed to offset calorie intake, promoting informed decisions for better health management
Emotions Tracking	Users can choose their current mood from the app's emotion list and track their feelings throughout the day for better emotional insight.	Diabetter's emotion tracking feature helps users observe how different emotions affect blood sugar levels, highlighting the importance of emotional awareness in diabetes management.
Daily Notifications	Diabetter provides personalized daily notifications that act as a digital assistant, offering nudges, advice, and support throughout the day.	Diabetter uses nudge theory and behavioral science to provide notifications that guide users and remind them throughout the day. These notifications help individuals with diabetes make decisions and prevent errors by offering clear guidance, ultimately giving users a sense of freedom in line with libertarian paternalism

Results

Through content analysis of different features necessary for the development of a mobile app, the primary version of the Diabetter application was designed for iOS and Android systems by using Swift and Java languages, respectively. The graphical format and user-interface screen of the iDia (initial version) and Diabetter (final version) are shown in Figures 1 and 2, respectively. In the finalized version of the application, an enhanced scoring feature was implemented, accompanied by an upgraded graphical interface for superior user experience [Figure 3].

After the optimization of the application, the users' interaction with Diabetter increased. The user must create an account for the first login, and after registration, they can enter their demographic and clinical information. In the primary version, the registration process was longer with more additional information, which caused many users to refuse the registration process. This was optimized in the updated version, and only the necessary information for the user scoring system was received and others were only received if needed. In the final version, the user does not need to enter information with the keyboard, which caused a significant increase in the rate of users completing their registration and using the app. Enhanced

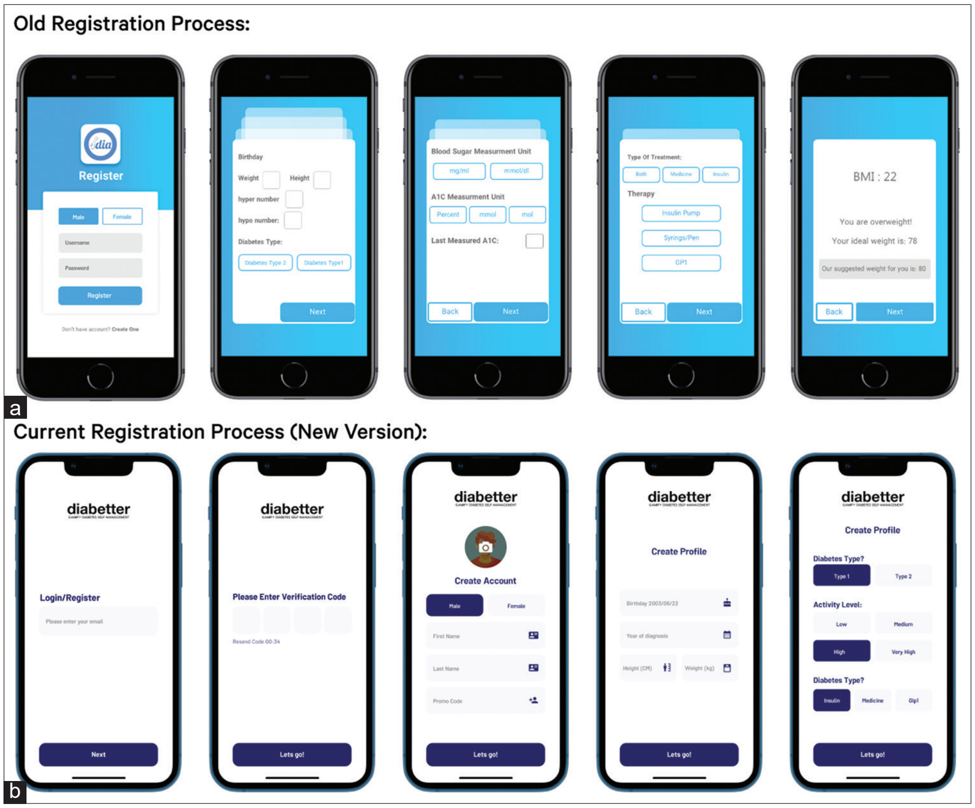

Figure 1: The registration sections and screenshots for initial (a) and upgraded (b) versions of the Diabetter application

Figure 2: The clinical information and the level of user activity in the initial (a) and upgraded (b) versions of the Diabetter application

recommendation algorithms within the application led to a higher engagement among active users, who frequently logged their blood glucose data. This resulted in a greater proportion of recorded blood glucose levels falling within the normal range.

The usability and user satisfaction of the application were evaluated in qualified participants. For this reason, 56 subjects aged 16–25 with a history of type 1 diabetes were included in the study; 38 of them were women, and 18 were men. Most of these patients were in the age group of 16 years. Based on hemoglobin A1C results at the beginning of the study, 11 subjects were in the group with optimal control (A1C < 7), 31 in moderate control ($7 <$ A1C < 9), and 14 in poor control (A1C > 9) groups [Table 1]. After a period of 3 months of using the Diabetter application, the number of people in the optimal control group increased to 19, four of whom were already in the same group. Nine subjects from the medium group and six from the poor control were transferred to this section. The subjects present in the moderate control increased to 32 people, 21 of whom were already in the same group. Four people from the optimal and seven from the poor control groups were transferred to this part. There were five people in the poor control group, two of them were from the optimal, one from the moderate, and two from the poor control group.

Overall, during the study period, a total of 40 subjects had a decrease in hemoglobin A1C, while it remained unchanged in four people and increased in 12. Interestingly, 21 subjects with A1C reduction had a higher score than the average value (12.39). However, three people with a score above the average showed an increase in A1C, and one person did not show any change [Table 2].

Table 2: Distribution of the Diabetter application user demographics and health metrics, categorized by gender, age, glycated hemoglobin (A1C) levels, and average engagement score

No.	Gender	Age	First A1C	End A1C	Average Score	A1C Difference	No.	Gender	Age	First A1C	End A1C	Average Score	A1C Difference
1	Female	16	6.5	4.7	2.19	−1.8	29	Female	17	8	7.1	7.06	−0.9
2	Male	21	7	5.1	2.80	−1.9	30	Male	25	10	7.1	14.62	−2.9
3	Female	21	7.3	5.2	8.24	−2.1	31	Male	17	8.8	7.2	3.19	−1.6
4	Female	16	10	5.3	3.75	−4.7	32	Female	24	7	7.3	4.37	0.3
5	Female	23	9	5.5	10.12	−3.5	33	Female	23	7.4	7.3	20.08	−0.1
6	Male	20	6.5	5.7	33.50	−0.8	34	Female	24	7.5	7.3	20.16	−0.2
7	Female	19	10	5.7	6.13	−4.3	35	Male	22	6	7.4	29.03	1.4
8	Female	25	11	5.7	19.89	−5.3	36	Female	21	9	7.4	22.86	−2.6
9	Female	24	7.5	5.9	2.37	−1.6	37	Female	24	7.5	7.5	5.73	0
10	Male	24	7.5	5.9	14.85	−1.6	38	Male	19	7.8	7.5	20.62	−0.3
11	Male	18	6	6	31.89	0	39	Male	25	9.5	7.5	12.93	−2
12	Female	23	5.6	6.1	4.97	0.5	40	Male	25	8	7.6	5.37	−0.4
13	Male	18	14	6.1	30.55	−7.9	41	Female	16	16	7.6	17.56	−8.4
14	Female	24	7.4	6.2	4.10	−1.2	42	Male	22	8.9	7.7	16.57	−1.2
15	Female	17	13	6.2	14.90	−6.8	43	Female	16	6.5	7.8	7.62	1.3
16	Female	21	7	6.3	10.52	−0.7	44	Female	21	8	7.9	2.79	−0.1
17	Female	18	9	6.3	18.43	−2.7	45	Male	20	13	7.9	4.19	−5.1
18	Female	19	13	6.3	7.58	−6.7	46	Male	22	8	8	18.09	0
19	Female	16	7	6.4	24.86	−0.6	47	Female	16	12	8	9.60	−4
20	Female	17	8	6.6	13.68	−1.4	48	Female	25	7.8	8.3	25.44	−0.5
21	Male	17	7.1	6.7	2.72	−0.4	49	Female	23	6.7	8.5	13.06	1.8
22	Female	25	9	6.7	7.17	−3.3	50	Female	18	12.6	8.7	20.93	−3.9
23	Male	16	7	6.9	3.07	−0.1	51	Female	22	11.1	8.8	9.11	−2.3
24	Female	23	6.8	7	10.82	0.2	52	Female	23	7.7	9.6	12.01	1.9
25	Female	25	7	7	6.01	0	53	Female	16	6.5	9.7	3.25	3.2
26	Female	25	8	7	9.75	−1	54	Male	20	9.6	10.2	5.02	0.6
27	Female	22	7	7.1	10.12	0.1	55	Female	16	6.9	10.6	26.13	3.7
28	Male	16	7.7	7.1	14.75	−0.6	56	Female	16	6	12.2	6.93	6.2

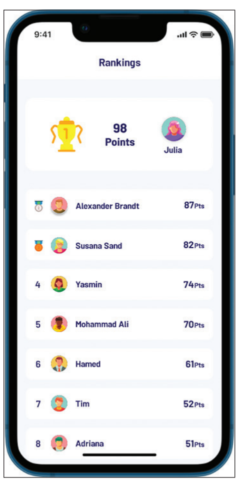

Figure 3: Schematic representation of the user scoring system in the Diabetter application

Discussion

Mobile-based applications represent a technological opportunity to explore new approaches for monitoring and self-care assessment in chronic conditions such as diabetes.[18,20] They can have access to various possibilities regarding their daily decision and habits, which are extremely important for their health condition. Considering that diabetes is a chronic disease, the patients have positive contributions to disease control by performing self-care activities. For this reason, a person should continuously monitor important factors, including blood glucose level, proper diet, adjustment of insulin dose, and regular physical activities. Thus, it seems that self-management and monitoring systems based on smartphone applications could reduce health problems, prevent late complications, and improve the quality of life of patients with diabetes.[11,21,22]

Numerous studies have demonstrated the efficacy of gamification techniques (GTs) and behavioral economics in aiding users to modify detrimental habits and enhance their diabetes management.[23,24] Following extensive research and consultations with diabetes experts, it became evident that a gap existed in the intersection of mathematics, diabetes management, and habitual behaviors. In response to this identified gap, we embarked on the creation of a scoring system designed to empower users in comprehending their diabetes status. This innovative scoring system not only addresses the user's diabetes status but also encompasses their lifestyle, utilizing challenges seamlessly integrated into the application. The objective is to induce positive behavioral changes by engaging users in a dynamic and interactive manner.

The HbA1c level decreased in patients who continuously used this application, and it seems that there is a direct relationship between the duration of application usage and HbA1c level. The Diabetter users who scored better by making more accurate decisions at key moments received a better understanding of how they were controlling their blood glucose, leading to lower HbA1C over time.

Motivation is considered critical to the success of a diabetic application in the case of helping users with diabetes management. Prior studies have shown that lack of motivation is associated with low adoption of diabetic applications. For diabetic patients, one of the causes of this lack of motivation is that they do not understand what they are doing in case of their diabetes management. Thus, by this scoring system, which is from 0 to 100, we simplify diabetic patients' diabetes management into a single number so that they will understand how they are controlling their diabetes. As diabetes is a lifelong disease, there should be a middleman to encourage the diabetic person to control their disease. For this reason, we provide smart notifications based on user status each day with their points. For instance, if a user has eaten foods with high carbohydrates during the rest of the day, the application will suggest them to eat food with lower carbohydrates to cover all groups of nutrition provided in the healthy eating index (HEI).

The clinical impact of smartphone apps for the improvement and reduction of HbA1c levels in different populations and conditions of diabetic patients is associated with complex interventions, and it is difficult for a proper and complete conclusion.[25,26] However, some studies have shown that long-term use of apps can have a dramatic decrease in HbA1c levels.[27,28]

One of the novel features of this application is a scoring system that gives points to users in terms of how to enter information and input factors. This feature can solve one of the common problems of using similar apps, which includes decreasing interaction over time, making it more effective for continuous providers' attention and self-management.

The scoring system could act as a nudge by shaping the choice architecture of people with diabetes and making it easier for them to choose healthy behaviors. The scoring system could also appeal to people's cognitive biases, such as loss aversion, social norms, or framing effects, to influence their decisions. For example, the scoring system could show people how much they could lose or gain by following or not following their diabetes plan, how their scores compare to other people with diabetes, and how their scores reflect their progress and achievements. The scoring system could also use positive reinforcement, such as praise, rewards, and gamification, to increase people's engagement and satisfaction.[29,30]

Previous reports have indicated that mobile-based applications can be useful in diabetes self-management, but their effectiveness largely depends on the time the user spends on disease management.[26] Thus, we created an intelligent scoring system based on the nudge theory, which can motivate patients and lead to more often contact with providers.

Conclusions

Based on the results, it seems that the Diabetter application will be greatly beneficial for diabetes self-management. The most important aspects of this application are suitable and easy-to-use preferences for both patients and doctors, as well as a scoring system for comparing the progress of users' results with each other, which can be very effective in increasing user knowledge-based skills for diabetes-related symptom relief and management; moreover, it will motivate the user to have a better score (which means better diabetes control) to be able to compete with other users. In addition, the clinical experts mentioned that they had a better understanding of the patient's condition since their last visits.

Acknowledgments

The authors thank all participants who agreed to take part in our study and for allowing us to assess their blood samples.

Author contributions

M.A.T and S.R.J contributed equally to the design, writing, and modification of the manuscript.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Received: 06 Oct 23 **Accepted:** 20 Feb 24
Published: 17 Jul 24

References

1. American Diabetes Association Classification and diagnosis of diabetes. Section 2. Standards of Medical Care in Diabetes—2018. Diabetes Care 2018;41(Suppl 1):S13–27.
2. Cho NH, Shaw JE, Karuranga S, Huang Y, da Rocha Fernandes JD, Ohlrogge AW, *et al*. IDF diabetes atlas: Global estimates of diabetes prevalence for 2017 and projections for 2045. Diabetes Res Clin Pract 2018;138:271–81.
3. Lin X, Xu Y, Pan X, Xu J, Ding Y, Sun X, *et al*. Global, regional, and national burden and trend of diabetes in 195 countries and territories: An analysis from 1990 to 2025. Sci Rep 2020;10:14790.
4. International Diabetes Federation. IDF Diabetes Atlas. 9th ed.

Brussels, Belgium; 2019. Available from: https://diabetesatlas.org/upload/resources/material/20200302_133351_IDFATLAS9e-final-web.pdf

5. Wu Y, Yao X, Vespasiani G, Nicolucci A, Dong Y, Kwong J, *et al*. Mobile app-based interventions to support diabetes self management: A systematic review of randomized controlled trials to identify functions associated with glycemic efficacy. JMIR mHealth uHealth 2017;5:e35.
6. Funnell MM, Brown TL, Childs BP, Haas LB, Hosey GM, Jensen B, *et al*. National standards for diabetes self-management education. Diabetes Educ 2007;33:599-614.
7. Svedbo Engström M, Leksell J, Johansson U-B, Gudbjörnsdottir S. What is important for you? A qualitative interview study of living with diabetes and experiences of diabetes care to establish a basis for a tailored Patient- Reported Outcome Measure for the Swedish National Diabetes Register. BMJ Open 2016;6:e010249. doi: 10.1136/bmjopen-2015-010249.
8. Cochran J, Conn VS. Meta-analysis of quality of life outcomes following diabetes self-management training. Diabetes Educ 2008;34:815-23.
9. Doupis J, Festas G, Tsilivigos C, Efthymiou V, Kokkinos A. Smartphone-based technology in diabetes management. Diabetes Ther 2020;11:607-19.
10. Debon R, Coleone JD, Bellei EA, De Marchi ACB. Mobile health applications for chronic diseases: A systematic review of features for lifestyle improvement. Diabetes Metab Syndr 2019;13:2507–12.
11. Whitehead L, Seaton P. The effectiveness of self-management mobile phone and tablet apps in long-term condition management: A systematic review. J Med Internet Res 2016;18:e97. doi: 10.2196/jmir.4883.
12. Holtz B, Lauckner C. Diabetes management via mobile phones: A systematic review. Telemed J E Health 2012;18:175–84.
13. Adu MD, Malabu UH, Callander EJ, Malau-Aduli AE, Malau-Aduli BS. Considerations for the development of mobile phone apps to support diabetes self-management: Systematic review. JMIR Mhealth Uhealth 2018;6:e10115. doi: 10.2196/10115.
14. Kwan YH, Ong ZQ, Choo DYX, Phang JK, Yoon S, Low LL. A mobile application to improve diabetes self-management using rapid prototyping: Iterative co-design approach in Asian settings. Patient Prefer Adherence 2023;17:1-11.
15. Veazie S, Winchell K, Gilbert J, Paynter R, Ivlev I, Eden KB, *et al*. Rapid evidence review of mobile applications for self-management of diabetes. J Gen Intern Med 2018;33:1167-76.
16. Ehrmann D, Eichinger V, Vesper I, Kober J, Kraus M, Schäfer V, *et al*. Health care effects and medical benefits of a smartphone-based diabetes self-management application: Study protocol for a randomized controlled trial. Trials 2022;23:282.
17. Istepanian RSH, Zitouni K, Harry D, Moutosammy N, Sungoor A, Tang B, *et al*. Evaluation of a mobile phone telemonitoring system for glycaemic control in patients with diabetes. J Telemed Telecare 2009;15:125–8.
18. Chomutare T, Fernandez-Luque L, Arsand E, Hartvigsen G. Features of mobile diabetes applications: Review of the literature and analysis of current applications compared against evidence-based guidelines. J Med Internet Res 2011;13:e65. doi: 10.2196/jmir.1874.
19. Arsand E, Tufano JT, Ralston JD, Hjortdahl P. Designing mobile dietary management support technologies for people with diabetes. J Telemed Telecare 2008;14:329–32.
20. Moses JC, Adibi S, Shariful Islam SM, Wickramasinghe N, Nguyen L. Application of smartphone technologies in disease monitoring: A systematic review. Healthcare (Basel) 2021;9:889.
21. Song M, Choe MA, Kim KS, Yi MS, Lee I, Kim J, *et al*. An evaluation of Web-based education as an alternative to group lectures for diabetes self-management. Nurs Health Sci 2009;11:277–84.
22. Sunil Kumar D, Prakash B, Subhash Chandra BJ, Kadkol PS, Arun V, Thomas JJ. An android smartphone-based randomized intervention improves the quality of life in patients with type 2 diabetes in Mysore, Karnataka, India. Diabetes Metab Syndr 2020;14:1327-32.
23. Priesterroth L, Grammes J, Holtz K, Reinwarth A, Kubiak T. Gamification and behavior change techniques in diabetes self-management apps. J Diabetes Sci Technol 2019;13:954-8.
24. Cafazzo JA, Casselman M, Hamming N. Design of an mHealth app for the self-management of adolescent type 1 diabetes: A pilot study. J Med Internet Res 2012;14:e70. doi: 10.2196/jmir.2058.
25. Martos-Cabrera MB, Velando-Soriano A, Pradas-Hernández L, Suleiman-Martos N, Cañadas-De la Fuente GA, Albendín-García L, *et al*. Smartphones and apps to control glycosylated hemoglobin (HbA1c) level in diabetes: A systematic review and meta-analysis. J Clin Med 2020;9:693.
26. Hou C, Carter B, Hewitt J, Francisa T, Mayor S. Do mobile phone applications improve glycemic control (HbA1c) in the self-management of diabetes? A systematic review, meta-analysis, and GRADE of 14 randomized trials. Diabetes Care 2016;39:2089-95.
27. Kirwan M, Vandelanotte C, Fenning A, Duncan MJ. Diabetes self-management smartphone application for adults with type 1 diabetes: Randomized controlled trial. J Med Internet Res 2013;15:1–14.
28. Zhai Y, Yu W. A mobile app for diabetes management: Impact on self-efficacy among patients with type 2 diabetes at a community hospital. Med Sci Monit 2020 26:e926719. doi: 10.12659/MSM.926719.
29. Joachim S, Forkan ARM, Jayaraman PP, Morshed A, Wickramasinghe N. A Nudge-inspired AI-driven health platform for self-management of diabetes. Sensors (Basel) 2022;22:4620.
30. Kwan YH, Cheng TY, Yoon S, Ho LYC, Huang CW, Chew EH, *et al*. A systematic review of nudge theories and strategies used to influence adult health behaviour and outcome in diabetes management. Diabetes Metab 2020;46:450-60.