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RESEARCH ARTICLE

Effect of mobile learning (application) on self-care behaviors and blood glucose of type 2 diabetic patients

Manizhe Hooshmandja[1] · Aeen Mohammadi[2] · Alireza Esteghamti[3] · Khadije Aliabadi[4] · Mohammadreza Nili[4]

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Abstract

Purpose More than 70% of the health expenditure is related to chronic diseases. Therefore, an efficient managerial program can markedly reduce medical and administrative costs and benefit both patients and service providers. The use of mobile technologies can be very helpful in this regard. This study was conducted to determine the effect of mobile learning (application) on self-care behaviors and blood glucose control of type 2 diabetic patients attending the Diabetes Clinic of Imam Khomeini Hospital Complex.

Methods This interventional, quasi-experimental study was conducted on 51 diabetic patients. The patients were randomly assigned to case and control groups, and a specifically designed application was used in the case group for three months. Self-care behavior, FBS, and HbA_1C were assessed in both groups before and three months after the intervention, and the results were analyzed after the intervention. The Summary of Diabetes Self-Care Activities (SDSCA) measure and medical records was used for data collection. Descriptive and inferential statics (paired t test, ANCOVA analysis) were used for data analysis.

Results The Mean ± SD of the self-care posttest score, FBS, and HbA_1C was 76.95 ± 7.94 vs. 43.4 ± 9.74 ($P = 0.001$), 143.58 ± 23.39 vs. 171.81 ± 36.98 (P = 0.001), and 6.84 ± 0.63 vs. 8.10 ± 0.10 (P = 0,001), in the case and control group respectively, indicating a difference in all cases.

Conclusions The results indicated the positive effect of the mobile application on self-care behavior, FBS, and HbA_1C.

Keywords Mobile learning · Application · Self-care · Blood glucose · Type 2 diabetic patients

Introduction

Nowadays there is an increasing tendency to use different technologies or mobile applications for learning purposes [1]. The capabilities of mobile technology provide a favorable ground for different educations. Learners can use their cellphones in different places and continue learning outside formal academic environments [2]. Mobility enables limitless learning. Mobile devices can be used for various rich communications and contribute to generation of collaborative knowledge [3].

Smartphones are very popular and the number of people who know how to use one increases every day. The main advantages of portable computers are encouraging responsibility, increasing motivation, helping with organizational skills, assisting in cooperative and independent learning, acting as a reference, and following the latest scientific findings and assessing them [4].

Mobile learning has recently entered the domains of health and treatment. Improved quality of learning has always been priority in medicine. Due to the nature and content of learning in medical sciences and patients-related issues, the use of multimedia is necessary to facilitate learning [5]. However, no serious attempts have been made to present appropriate educational programs in this regard, mainly due to lack of time, hectic work schedule of healthcare providers, and lack of trained staff that are familiar with new educational methods according to different studies [6]. This is while patients require frequent interactions with the

✉ Aeen Mohammadi
aeen_mohammadi@tums.ac.ir; aeen@yahoo.com

1 Virtual University of Medical Science, Tehran, Iran

2 Department of E-Learning in Medical Education, Virtual School, Tehran University of Medical Sciences, Dolatshahi, Naderi St, Keshavarz Blvd, Tehran 14166-14741, Iran

3 Department of Internal Medicine, Tehran University of Medical Sciences, Tehran, Iran

4 Department of Instructional Technology, Faculty of Psychology and Educational Sciences, Allameh Tabataba'i University, Tehran, Iran

health care system, high quality, evidence-based care should be constantly provided for many of them [7].

One of the technologies that can provide health care services for a large population is the mobile technology, known as mobile learning. It is an example of communications technologies that have found their way into education and learning. This type of learning has created a new definition of education, which enables learning in any place at any time using new methods [8].

Koole et al. [9] believe that mobile learning expands and improves the learners' capability to interact with one another and acquire information through wireless and mobile devices [9]. Brown [10] argues that mobile learning has the potential to enhance learning compared to electronic learning environments. Some methods used in mobile learning include short message services (EMS, simple animation, voice message), chat, online personal information management, online references and publications, MMS (sending multimedia content, including image, audio, and movie files to and from a cell phone), learning management systems for mobile learning, electronic support systems in mobile environments like cell phones and handheld PCs (like Personal Digital Assistant, PDA), and personal media players. These methods enable learning in different environments and remove many limitations and barriers [8].

Research has shown that the information people acquire from information technologies changes their health behaviors, affects their health decisions in 33–48% of the cases, and makes them visit a physician or seek health counselling in 12–14% of the cases [11, 12]. Diabetic patients are a group of patients that need such care. Diabetes is a serious chronic disease that imposes social and economic burdens all over the world [13]. Currently there are about 246 diabetic patients across the world and it is estimated that the figure will reach 380 million by 2025 [14]. The prevalence of diabetes is estimated 8.7% in the 15–64-year-old Iranian population. Moreover, the prevalence of type 2 diabetes is 4–4.5% in the Iranian population and more than 14% in people above 30 years [15].

Since diabetes is a chronic disease, a diabetic patient should cooperate in all stages of disease control and treatment and perform self-care activities. Self-care is a very important component of diabetes control and includes self-monitoring of blood sugar, diet, drug dose adjustment, and physical activity [16]. Use of new technologies in relationship with patients and emphasis on enhancing self-care activities are among methods applied for continuous monitoring of diabetic patients [17], and mobile phones play an important role in delivering this technology to patients [18].

Ferrer-Roca et al. [19] showed that intervention through mobile phone text messaging (SMS) is a simple, fast, and low-cost method for medical management of diabetes. El-Galyar et al. [20] conducted a study entitled "Mobile applications for self-management of diabetes patients" and concluded that mobile applications had potentially positive effects on diabetes self-management. The results also showed that the use of mobile applications were associated with an improvement in attitude towards diabetes self-management. Zakeri Moghaddam et al. [21] who reported that nurse-led telephone follow-up improved adherence to diabetic diet in type 2 diabetic patients. Azemat, Pedram & Shadan [22] showed that both mobile phone text messaging (SMS) and nurse-led telephone follow-up caused a significant improvement in adherence to the diabetic diet. Sacco et al. [23] reported regular telephone counselling for six months improved physical activity in type 2 diabetic patients. Parizad et al. [24] also reported the positive effect of tele-education on physical activity of patients suffering from type 2 diabetes mellitus. Jalilian, Zinat Motlagh & Solhi [25] reported no significant improvement in the self-monitoring of blood glucose after an educational intervention.

In the current situation that the cost of care is on the rise, due to the easy access without any constraints to mobile technology and the low cost of this educational method, it is necessary to consider this method as an effective way to educate patients with similar educational needs. Considering the potential capacities of mobile technology in health education, self-care, and public health, authorities are now paying more attention to the benefits of its use in the health domain. Therefore, we conducted this research to test the following hypotheses:

1- Use of mobile applications in patient education improves self-care behaviors of diabetic patients.
2- Use of mobile applications in patient education improves blood sugar control in diabetic patients.

Methods

This quasi-experimental study was conducted using a pretest-posttest controlled design in 2017. The participants were non-randomly assigned to case and control groups in order to prevent contamination, that is the case group members couldn't give the application to control group members. The research population was all diabetic patients attending the Diabetes Clinic of Imam Khomeini Hospital Complex affiliated with Tehran University of Medical Sciences. In this study, convenience sampling was applied to select 24 subjects in the case and 27 individuals in the control group. The inclusion criteria were a confirmed history of type 2 diabetes, having an Android smartphone, ability to read and write, willingness to join the study, and lack of diabetic complications. The Summary of Diabetes Self-Care Activities (SDSCA) measure developed by Toobert et al. [26] was used to determine the effect of mobile learning on self-care behaviors and blood sugar control. The SDSCA measure has two sections. The first section contains questions on demographic variables like age, sex, education, and occupation. The second section includes questions on diabetes self-care behaviors. It is a 15-item self-report questionnaire that evaluates self-care measures in the past seven days, including general and specific diet (5 questions), sport (2 questions), fasting blood sugar (2 questions), insulin or anti-diabetic pills (1 questions), foot care (4 questions), and smoking (1 question) [26].

In this measure, except for smoking that receives a score of zero or one, other behaviors are scored from zero to seven, and the total score is calculated by adding the scores of different questions, ranging from 0 to 99. The reliability and validity of the Persian version of the SDSCA were confirmed in previous studies [27]. In this research, we assessed the validity of the SDSCA using the content validity by education experts and endocrinologists and a Cronbach's alpha of 0.84 was obtained.

After preparing the content (self-care subscales) of the application and confirming its content validity by an endocrinologist, the educational design and scenarios of different parts of the application were prepared. Different parts of self-care education included blood sugar control by the patient, diet, dosing of insulin and anti-diabetic drugs, regular exercise, and smoking. In this application, the users were able to create a personal profile, use texts in short menus for education of self-care subscales, use images to understand the texts better, send e-mails to the researcher, forward test results to the researcher, record their blood sugar every day for self-monitoring and control purposes, see blood sugar records, and record insulin and other drugs and their doses. The application also reminded the time of using drugs, sent messages to patients every day, and taught self-care subscales. The application could be accessed at any time and place without an Internet connection.

After preparing the self-care application for type 2 diabetic patients and obtaining the approval of the Ethics Committee of Tehran University of Medical Sciences, the researcher attended the Diabetes Clinic of Imam Khomeini Hospital Complex and the private office of a professor of endocrinology to start the sampling process. Sampling was continued for two weeks. The participants were assured that they could leave the study at any time without any effects on their treatment course, and informed consent was obtained from all of them. The data of the subjects were collected before and after the intervention, and their telephone numbers were recorded for further follow-up. The SDSCA measure was completed by subjects in the case and control groups before the intervention. The control group then received routine care as usual while the application was installed on the cell phone of subjects in the case group. The researcher also taught the cases how to use the application and gave them his cell phone number to contact him if they had any questions. The medical records of the patients were also evaluated for FBS and HbA_1C. The intervention continued for three months. After that, the researcher contacted the participants in the case and control group for a posttest. The new FBS and HbA_1C of the patients were also recorded. No intervention was done in the control group. In addition to providing educational material, each patient could register his/her daily blood glucose and medications in the application and compare with previous records. Application in this study was not provided through Web and the researcher installed the application on patients' mobile phones in the experimental group which was inaccessible for the control group.

Descriptive and inferential statistics (paired t test and ANCOVA) were used for data analysis.

Results

Male and female subjects comprised 20.8% and 79.2% of the participants in the case group and 25.9% and 74.1% of the individuals in the control group, respectively. About 8.3% of the subjects in the case group and 25.9% of the participants in the control group were in the age group 30–40 years. In both groups, 33.3% were in the age group 51–60 years and 33.3% were in the age group 61–70 years. In the control group, 29.6% had secondary school education, 37% had high school diploma, and 33.3% had university education (associate and bachelor's degree). In the case group, 33.3% had high school diploma, 50% had university education (associate and bachelor's degree), and 16.7% had a master's degree or PhD. There was no significant difference in the mean age, sex ratio, and education level between cases and controls.

Table 1 shows the mean FBS and HbA_1C before and after the intervention in case and control groups. Paired t-test showed no significant change in the mean FBS and HbA_1C before and after the intervention in the case group, while the difference was significant in the control group. FBS and HbA_1C increased and were not controlled in the control group, but the use of the application contributed to the control of FBS and HbA_1C in the case group.

According to Table 2, there was a small difference between the two groups on pretest (total self-care score: 44.75 ± 8.76 in the case group versus 44.48 ± 9.74 in the control group). However, the posttest results showed a significant difference between the two groups (total self-care score: 76.95 ± 7.94 in the case group versus 43.4 ± 9.74 in the control group). A significant difference was also observed in the score of self-care subscales between the two groups after the intervention. The mean posttest score of smoking was $91 \pm 0.28/1$ in the case group and 1.85 ± 0.36 in the control group, which showed no significant difference. ANCOVA, considering the results of pretest as

Table 1 Comparison of Mean and SD of FBS and HbA_1C in case and control groups before and after intervention using paired t-test

Groups	Variables	Before Intervention Mean ± SD	After Intervention Mean ± SD	T	P
Control Group	FBS	139.05 ± 28	171.81 ± 36.98	−5.094	.000
	A1C	6.85 ± 0.93	8.10 ± 0.10	−7.062	.000
Case Group	FBS	140.59 ± 37.83	143.58 ± 23.39	−.219	.829
	A1C	7.10 ± 1.22	6.84 ± 0.63	1.243	.232

Covariance, showed a significant difference in the total score of self-care and all of its subscales after the intervention ($P < 0.001$) except for smoking ($P < 0.729$) (Table 3). Before performing ANCOVA we tested its assumptions (normality of distribution, homogeneity of variance, linearity of relationship between the dependent variables and the covariate, and homogeneity of regression slopes).

Table 3 shows a significant difference in FBS and HbA_1C between the case and control groups after adjusting for pretest. Therefore, the null hypothesis was rejected in both research hypotheses.

Discussion

The results of this study showed a mean difference of 33.35 scores in the SDSCA between case and control groups after the intervention, and one-way analysis of covariance confirmed the significance of this difference at the level of 1%. Therefore, it can be stated that this application had a positive effect on self-care behaviors of type 2 diabetic patients. The findings of the present study were consistent with the results of study conducted by Fattah Nasab [28], Krishna & Boren [29], Faridi et al. [30], Liang et al. [31], Peeters, Wiegers & Friele [32], El-Galyar et al. [20], Sieverdes et al. [33], Naghibi et al. [34], and Hou et al. [35].

The results of a study by Ferrer-Roca et al. [19] showed that intervention through mobile phone text messaging (SMS) is a simple, fast, and low-cost method for medical management of diabetes. El-Galyar et al. [20] conducted a study entitled "Mobile applications for self-management of diabetes patients" and concluded that mobile applications had potentially positive effects on diabetes self-management. The results also showed that the use of mobile applications were associated with an improvement in attitude towards diabetes self-management.

The results of our study showed a significant difference in all subscales except smoking. It seems that stronger motives are required to change the smoking habit.

The results of the subscale of diet in our study were consistent with the findings of a study by Zakeri Moghaddam et al. [21] who reported that nurse-led telephone follow-up improved adherence to diabetic diet in type 2 diabetic patients. Moreover, Azemat, Pedram & Shadan [22] showed that both mobile phone text messaging (SMS) and nurse-led telephone follow-up caused a significant improvement in adherence to the diabetic diet.

As for the subscale of sports, Sacco et al. [23] reported regular telephone counselling for six months improved physical activity in type 2 diabetic patients. Parizad et al. [24] also reported the positive effect of tele-education on physical activity of patients suffering from type 2 diabetes mellitus. Similarly, Razmara, Hemmati & Khalkhali [36] noted a significant improvement in physical activity after an educational intervention. However, contrary to our findings, Kim et al. [37] reported no significant difference in the mean score of physical activity in diabetic patients following a telephone-delivered intervention. Access to the mobile application at

Table 2 Comparison of Mean and SD of score of self-care behavior and its subscales in case and control groups before and after intervention using ANCOVA analysis for adjusting pretest

Variables	Mean ± SD		Mean ± SD		**F**	**P**
	Before Intervention		After Intervention			
	Control Group	Case Group	Control Group	Case Group		
Diet	18.44 ± 4.35	16.25 ± 3.62	17.92 ± 4.3	26.7 ± 3.51	214.43	0.001
Sport	3.22 ± 3.35	3.04 ± 2.51	3.33 ± 3.34	8.45 ± 2.3	176.34	0.001
Fasting Blood Sugar	4.51 ± 4.20	3.54 ± 3.95	4.48 ± 4.11	9.12 ± 3.04	195.17	0.001
Insulin or anti-diabetic pills	5.44 ± 1.36	5.62 ± 1.17	3.14 ± 1.48	6.87 ± 0.44	56.09	0.001
Foot care	12.85 ± 3.87	13.91 ± 5.17	13.55 ± 3.9	25.79 ± 3.09	228.93	0.001
Smoking	1.81 ± 0.39	1.87 ± 0.33	1.85 ± 0.36	1.91 ± 0.28	0.121	0.729
Self-Care	44.48 ± 9.74	44.75 ± 8.76	43.4 ± 9.74	76.95 ± 7.94	55.18	0.001

Table 3 ANCOVA of FBS and HbA_1C with adjusting pretest

	Squares		Mean Square		F		P
	FBS	A1C	A1C	FBS	A1C	FBS	
Corrected Model	16,755.094	22.362	8377.547	11.181	15.459	28.927	.000
pretest	10,039.188	9.267	10,039.188	9.267	18.526	23.976	.000
error	17,341.077	11.982	541.909	.387			

any time and place and forwarding text messages to the patients regarding the importance of physical activity in blood sugar control on a daily basis may explain this difference.

As for the subscale of FBS self-monitoring, Lorig et al. [38] evaluated diabetes self-management with and without telephone follow-up and reported that telephone reinforcement improved blood sugar self-monitoring in the reinforced group with a significant difference between the two groups. Contrary to these findings Jalilian, Zinat Motlagh & Solhi [25] reported no significant improvement in the self-monitoring of blood glucose after an educational intervention. The reason for this discrepancy may be that the mobile application in our research allowed patients to record their blood sugar level every day and view the values for previous days for comparison, which encouraged self-monitoring.

The results of our research regarding insulin and anti-diabetic pills were consistent with the results of studies conducted by Parizad et al. [24] and Turner et al. [39]. Turner et al. studied type 2 diabetic patients and showed that telehealth monitoring via telephone follow-up improved adherence to medical regimen, which is consistent with the results reported by Razmara, Hemmati & Khalkhali [36]. The reason for this discrepancy may be that the mobile application allowed patients to record the dosing and timing of drug administration and reminded them to use their drugs, which helped them to further adhere to their drug regimen.

Regarding foot care, consistent with our results, Parizad et al. [24] also reported that the mean score of foot care improved significantly in type 2 diabetic patients after tele-education by telephone and SMS. The results of a study by Hajbaghery and Alinaghipoor [40] revealed that foot self-care education increased the patients' knowledge and performance about foot care and decreased the rate of diabetic foot ulcer and admission for treatment of foot ulcer.

Our findings regarding the subscale of smoking were in good agreement with the results of studies conducted by Agha Molaei, Eftekhar & Mohammad [41] and Jalilian, Zinat Motlagh & Solhi [25].

The overall results of this study showed better FBS and HbA_1C control in the case group versus the control group, and one-way ANCOVA confirmed the significance of this difference between the two groups. Liang et al. [31], Bell et al. [42], and Hou et al. [35] also reported similar findings. Liang et al. [31] showed that mobile phone interventions have a positive effect of blood sugar control in type 2 diabetic patients. Bell et al. [42] reported that mobile phone-based video messages for diabetic self-care have a positive effect on blood sugar control. The results of a study by Hou et al. [35] also revealed that mobile phone applications have a positive effect on blood sugar control in diabetic patients. According to the results of a study by Shakerzadeh et al. [43], mobile phones have an effective role in different aspects of diabetes management, including blood sugar and HbA_1C control, adherence to diet and drug regimen, regular exercise, and improved quality of life.

Conclusion

The results of this study rejected the null hypothesis, indicting the positive effect of intervention. Since these patients have received their education, sometimes even academic education, through conventional methods, presenting information via an interesting educational technology may enhance their learning. This educational innovation may even increase their attention to and interest in learning, resulting in improved learning outcomes. The above reasons justify the use of mobile applications in diabetic patients for educational purposes. Previous studies have also shown the benefits of using mobile applications.

Diabetic patients are usually older and busier than school and university students, and these differences should be considered in designing appropriate educational applications. These patients also have less patience and attention compared to other learners; therefore, the educational content of these applications should be interesting, useful, and concise. Inattention to the above points may result in failure and frustration in these patients. Moreover, to enhance the effectiveness of mobile applications, the educators of these patients should change their attitude towards this educational method and welcome innovations in this area.

In this research, the subjects in the case and control groups were selected via purposive and convenience sampling, and the duration of the research was three months. The long-term effects of the application on diabetic patients should be assessed in future studies. Moreover, it is wise to assess this educational method in diabetic patients suffering from diabetic complications and in type 1 diabetic patients.

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Compliance with ethical standards

Conflict of interest The authors declared that they have no conflict of interest.

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