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THE EFFECT OF SMARTPHONE APPS AND TECHNOLOGY COMPATIBILITY ON DIABETES CONTROL IN DIABETIC PATIENTS USING INSULIN

İNSÜLİN KULLANAN DİYABET HASTALARINDA AKILLI TELEFON UYGULAMALARI VE TEKNOLOJİYE UYUMUN DİYABET KONTROLÜ ÜZERİNE ETKİSİ

Mustafa KAHRAMAN[1], Ramazan ÇAKMAK[2], İlhan SATMAN[3,4], Kubilay KARŞIDAĞ[3], Şükrü ÖZTÜRK[5], Meryem Merve ÖREN[6], Mehmet Akif KARAN[7]

[1]Istanbul University, Istanbul Faculty of Medicine, Department of Physiology, Istanbul, Turkey
[2]Başakşehir Çam and Sakura City Hospital, Endocrinology and Metabolism Diseases, Istanbul, Turkey
[3]Istanbul University, Istanbul Faculty of Medicine, Department of Internal Medicine, Department of Endocrine and Metabolic Diseases, Istanbul, Turkey
[4]TUSEB Turkey Institute of Public Health and Chronic Diseases, Istanbul, Turkey
[5]Istanbul University, Istanbul Faculty of Medicine, Department of Internal Medicine, Division of Medical Genetics, Istanbul, Turkey
[6]Istanbul University, Istanbul Faculty of Medicine, Public Health Department, Istanbul, Turkey
[7]Istanbul University, Istanbul Faculty of Medicine, Department of Internal Medicine, Department of Geriatrics, Istanbul, Turkey

ORCID IDs of the authors: M.K. 0000-0002-5775-5928; R.Ç. 0000-0003-3815-7444; İ.S. 0000-0001-8613-1797; K.K. 0000-0002-9332-1262; Ş.Ö. 0000-0002-8809-7462; M.M.Ö. 0000-0002-3383-7830; M.A.K. 0000-0002-9080-404X

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ABSTRACT

Objective: This study was done to determine the need for technological systems in diabetes patients using insulin in Turkey, and to investigate the relationship between diabetes control and their smartphone apps.

Material and Methods: This descriptive cross-sectional type of study was carried out with 506 diabetic patients using insulin who were followed up at the Diabetes Outpatient Clinics within the Department of Internal Medicine, Istanbul University Istanbul Medical Faculty, between March and September 2017. The data were obtained with a face-to-face interview of the physician using the data collection form.

Results: The mean age of the participants was 54.23±15.23 (18-89) years. The investigation of distribution in accordance with age showed that 71 patients (14%) were in the 18-34 age group, 302 (59.7%) in the 35-64 age group, and 133 (26.3%) were aged 65 years and above. The rate of those with Type 1 diabetes was 22.9% (n=116) and the rate of those with Type 2 diabetes was 77.1% (n=390). Four-hundred and sixty-four (92.5%)

ÖZET

Amaç: Türkiye'de insulin kullanan diyabet hastalarında teknolojik sistemlere duyulan ihtiyacın belirlenmesi ve akıllı telefon uygulamalarının diyabet kontrolü ile ilişkisinin araştırılması amaçlanmıştır.

Gereç ve Yöntemler: Tanımlayıcı kesitsel tipte tasarlanan çalışma Mart ve Eylül 2017 tarihleri arasında Istanbul Üniversitesi, İstanbul Tıp Fakültesi, İç Hastalıkları Bölümü bünyesindeki Diyabet Polikliniklerinde takip edilen ve insulin kullanmakta olan 506 diyabet hastası ile gerçekleştirildi. Veriler, hazırlanan veri toplama formu yardımı ile görevli doktor tarafından yüz yüze görüşme yöntemi kullanılarak elde edildi.

Bulgular: Katılımcıların yaş ortalaması 54,23±15,23 (18 ile 89) yıl idi. Yaş kategorilerine göre dağılım incelendiğinde; 71'i (%14) 18-34, 302'si (%59,7) 35-64 yaş aralığında, 133'ü (%26,3) ise 65 yaş ve üstü grupta bulunmaktaydı. Tip 1 diyabet olanların oranı %22,9 (n=116), tip 2 diyabet olanlar ise %77,1 (n=390) idi. Hastaların 468'i (%92,5) diyabet hastalarının yaşam kalitesini artıracak ülkemize özgü bir hasta takip sisteminin faydalı olacağını

Corresponding author/İletişim kurulacak yazar: mkahraman@istanbul.edu.tr

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of the patients stated that a patient follow-up system specific to our country would be useful in increasing the quality of life for diabetic patients. Three-hundred and twenty-one (63.4%) of the patients stated they have been using applications on - technological and telecommunication devices, and 185 patients (36.6%) stated they did not use the applications. In the model that examined the factors affecting the use of smartphone applications (Nagelkerke R2=44.6%, sensitivity=82.9% specificity=69.2%), it showed that higher education students' rate of using smartphone applications was 14.7 times higher than those with lower education; and those with an income level between 2 and 4 times above minimum wage were found to be 2.5 times higher than those with an income level of or below minimum wage.

Conclusion: It is anticipated that a system specific to our country will be needed for diabetic patients using insulin and that educated young patients with middle income will be highly interested in this system.

Keywords: Insulin-dependent diabetes mellitus, technological innovations, applications

belirtti. Hastaların 321'i (%63,4) teknolojik iletişim ve haberleşme cihazlarındaki uygulamaları kullandığını, 185'i (%36,6) ise kullanmadığını belirtti. Akıllı telefon uygulaması kullanımını etkileyen faktörlerin incelendiği modelde (Nagelkerke R2=%44,6, duyarlılık=%82,9 özgüllük=%69,2) yüksek eğitim görenlerin akıllı telefon uygulaması kullanma oranı, eğitimi olmayanlara göre 14,7 kat; gelir seviyesi asgari ücretin 2 ile 4 katı arasında olanlar da ise gelir seviyesi asgari ücret ve altında olanlara göre 2,5 kat daha yüksek bulundu.

Sonuç: İnsülin kullanan diyabet hastaları için ülkemize özgü bir sisteme ihtiyaç olduğu ve bu sisteme genç eğitimli ve gelir seviyesi orta yüksek olan hastaların ilgilerinin yüksek olacağı öngörülmektedir.

Anahtar Kelimeler: İnsülin bağımlı diyabet, teknolojik yenilikler, uygulamalar

INTRODUCTION

Diabetes is a metabolic disease that emerges with absolute or relative insulin deficiency or inadequate efficiency of insulin characterized by an increase in the blood glucose level which requires continous follow-up because of its chronic nature and the complications that can ensue (1).

Tha data of the World Health Organisation (WHO) published in 2014 showed that the number of diabetic patients was more than 422 million worldwide. The estimates of WHO showed that approximately 3.4 million of diabetes patients died of hyperglycemia each year (2). The recently published 9th Diabetes Atlas by the International Diabetes Federation reported that the prevalance of type 2 Diabetes has been increasing, and 79% of diabetes patients have been living in low-middle income countries. The same publication reported that approximately 700 million individuals diagnosed with diabetes are expected to reach the ages of 20-79 years in 2045 (3).

The TURDEP-II study performed in 2010 in Turkey reported that the prevalance of diabetes increased to 13.7%, and the number of patients diagnosed with diabetes was estimated to be 6.5 million (4). Performing the same ratio in the population at present showed that the number of diabetic patients can exceed 8.5 million (5).

The cost of chronic diseases was investigated in the report named "Chronic disease: an economic perspective" prepared with the cooperation of the World Health Organisation and The Oxford Health Alliance. The health spending per individual was calculated as $9,206 and higher in the mid-high income group of developed countries, between $2,976 - $9,205 in the low-mid income group countries, and $2,975 and below in low income group countries in the report in accordance with the data of the World Bank (6).

Diabetes is one of the biggest problems increasing healthcare costs, causing a significant burden for the global world and all countries. The cost of diabetes to the world economy in 2015 has a mean of approximately 1.32 trillion American Dollars (7). The total health expenditures for diabetes was 23.8% for the age group of 20-79 years in Turkey. In 2018, the data in Turkey showed that the annual cost of diabetes and its complications was 40 billion Turkish liras (3).

The use of mobile technological devices in the follow up and treatment of chronic diseases, especially in the follow up and treatment of diabetes has become more popular. The use of telemedicine practices and mobile applications can overcome geographical burdens, provide close follow-up, and create an opportunity for a patient to give feedback about their diabetes management (8). In addition, health applications offered for the use of diabetic patients provide management of insulin need and automatic feedback on blood glucose levels. Mobile applications with more features were reported to be used by an increasing number of individuals, enabling better self-management of their diabetes management (8). This study was designed to investigate the use of smart phone applications developed for use in Turkey of insulin dependent diabetes patients for diabetes control.

MATERIALS AND METHODS

The research design

The study designed as a descriptive cross-sectional type was conducted with 506 diabetic patients who used insulin, and were followed up in Istanbul University Istanbul

Faculty of Medicine Department of Internal Medicine from March 2017-September 2017.

The participants were informed about the study, and their informed consents were obtained. The data were obtained with a face-to-face interview method by the associated physician with the prepared data form. The use of applications by patients in smart phone or similar devices (tablet, smart watch, and smart wrist band, etc.) was taken as the basis for technology use criteria.

The ethics board approval was granted from Istanbul University Clinical Research Ethics Board with (Date: 10.03.2017, No: 268). The study was reported in appropriate with the STROBE guide.

The environment of the research

The Department of Internal Medicine in Istanbul Faculty of Medicine is a unit which serves more than a half million people annualy with 25 outpatient clinics with a 226 bed capacity.

Participants

The study was conducted with diabetic patients who used insulin, and were followed up in the diabetes outpatient clinic of Istanbul University, Istanbul Faculty of Medicine Department of Internal Medicine from March 2017-September 2017. The systematic sampling method was used in selection of the participants. Accordingly, patients with five or over registrations were included in the study.

Inclusion criteria

1. Having received insulin treatment in the last six months
2. Older than 17 years

Exclusion criteria

1. Pregnant
2. Paralysis
3. Unable to speak Turkish at a level to understand questions, and to respond

Variables

The primary result criterion of the study was identified as glycolysated hemoglobin (HbA1c). In addition, age, sex, height, weight, diseases, education and income data, received treatments, compliance to treatment, the ability to count carbonhydrates, severe hypoglycemia experiencing conditions, the reasons for experiencing hypoglycemia and hyperglycemia symptoms, physical activity conditions, and technological device use conditions of the participants were noted on the prepared data forms. The body mass index (BMI: Body weight/Height^2) was calculated. The glycolysated hemoglobin (HbA1c), fasting blood glucose (FBG), lipid profile (HDL, and LDL chloresterol, triglyceride), creatinine, and microalbuminuria levels, glomerulary filtration rate (GFR), and systolic/diastolic blood pressures (BP) calculated in the last three months were evaluated from the patient files. The cutting points for evaluating the urinary albumin excretion were taken as normo 30 mg/g, micro between 30-299 mg/g, and macroalbuminuria ≥300 mg/g.

Diabetes associated complications (retinopathy, neuropathy, and nephropathy) were investigated from the patient files as appropriate with current standard descriptions. The patients were asked whether they omitted insulin doses, whether they forgot and reinjected their injections for evaluating the compliance of diabetic patients to treatment protocols, and for investigating new technological methods for enabling patients to adhere to blood glucose regulations. Smart phone application use was checked to see whether individuals used the e-pulse, blood glucose follow up or other health practices on their phones during any period of the disease.

Sample size

The sample measuring of the research was performed using the G*Power 3.1.9.7 program. Because the main variable of the study was numerical, the model which can compare the means between two independent groups based on the t test assumptions was selected. A difference of 0.6 unit for HbA1c between the groups, and taking the standard deviations as 2.0 showed the effect width as 0.3. Accordingly, 484 individuals were required to obtain a strength of 95% in the analysis conducted with the assumption of the effect width as 0.30 (small-medium), and the α error as 0.05.

Statistical analysis

The data were analysed using the Statistical Package for the Social Sciences 21.0 software (SPSS Inc., Chicago, IL, USA). The continous data in the descriptive statistics were given with mean±standard deviation (SD), and categorical data were given with number, and percentage values. The Kolmogorov-Smirnov analysis was used to evaluate the appropriateness of the normal distribution for continous data in the statistical comparison of the data. The t test was used for parametric data in the presence of two independent groups in the comparison, the Mann-Whitney U test for nonparametric data, and the Chi square test was used in the comparison of categorical data.

The multivariate logistic regression analysis was performed using the independent variables detected to be effective on technology use in univariate analyses for evaluating the effects of these independent variables on one another, and for detecting which of these technology use behaviors were mostly effective. The model with the highests descriptive feature among these created models was used. Hosmer-Lemeshow test was used for model compliance. P value smaller than 0.05 was accepted adequate for the statistical significance.

RESULTS

Descriptive results

The mean age of the participants was 54.23±15.23 (18 to 89 years) years. The distribution in accordance with the age categories showed that 71(14%) were between 18-34 years old, 302 (59.7%) were between 35-64 years old, and 133 (26.3%) were aged 65 years and over. The rates of patients diagnosed with type 1 diabetes (T1DM) was 22.9% (n:116), and the rates of patients with type 2 (T2DM) diabetes was 77.1% (n:390). Three-hundred and twenty-one of the patients (63.4 %) were reported to have used applications on technological communication and telecommunication devices, however 185 patients (36.6%) reported not to have used these devices. Ninety-nine percent of participants (n:467) were reported to have communicated with their physician following up their diabetes by presenting to the outpatient clinic. Four-hundred and sixty-eight of the patients (92.5%) reported that a patient follow up system to increase the quality of life for diabetes patients specific to Turkey would be beneficial.

Paired comparisons

The age, BMIs, microalbumin, creatinine, triglyceride, and systolic blood pressures of patients who used smart phone applications were found lower when compared with nonusers, however their GFRs were found higher as compared with the nonusers. There was no statistically significant difference detected in the evaluation of the HbA1c levels in the last three months (Table 1).

Although the rate of type 1 DM was higher in patients who used smart phone applications as compared with patient nonusers, the prevalence in detecting complications was lower. However, no statistically significant difference was detected in the comparison of sex between the groups (Figure 1) (Table 2).

The conducted analyses revealed that the patients who used smart phone apps were more educated, with higher incomes, who performed more exercises, and were detected to have less complications (Table 2).

Multivariant analyses

The logistic regression model developed to estimate the smart phone application users was detected to have the Nagelkerke R^2 value of 44.6%, sensitivity of 82.9%, and specificity of 69.2% (Table 3).

The model investigating the factors affecting the use of smart phone applications showed that the smart phone application use ratios of patients with higher education were 14.7% higher compared with the ratios in patients with less education; and was 2.5% higher in patients with an income level between 2-4% above minimum wage as compared with the ratios of patients with minimum wage income or less (Table 3).

DISCUSSION

Key findings

Four-hundred and sixty-eight of the patients (92.5%) indicated that a patient follow up system specific to our

Table 1: The comparison of the laboratory results in accordance with the smart phone application use of patients

	The use of smart phone application					
	No		Yes			
	Mean	SD	Mean	SD	Z/t	p
Age (year)	63	10	49	15	10.148	**<0.001**
BMI (kg/m^2)	30.65	6.22	28.73	6.66	3.275	**0.001**
DM period (year)	18	10	14	9	4.509	**<0.001**
FBG (mg/dL)	181	82	192	90	1.414	0.157
HbA1c (%)	9.4	2.4	8.9	2.0	1.467	0.142
Microalbuminuria (mg/day)	181.4	486.6	119.0	375.9	3.290	**0.001**
Creatinine (mg/dL)	1.1	0.9	0.9	0.8	3.381	**0.001**
GFR (%)	80.64	37.86	110.98	39.39	4.305	**<0.001**
SBP (mmHg)	131	18	126	18	2.860	**0.004**
DBP (mmHg)	75	12	77	11	1.798	0.072
Triglyceride (mg/dL)	188	119	176	156	2.435	**0.015**
HDL Chloresterol (mg/dL)	46	15	49	18	0.919	0.358
LDL Chloresterol (mg/dL)	120	38	113	41	1.815*	0.070

SD: Standard deviation, Z: Mann-Whitney U test value, t: t test value in independent groups, BMI: body mass index, DM: Diabetes mellitus, GFR: Glomerulary filtration rate, SBP: Systolic blood pressure, DBP: Diastolic blood pressure

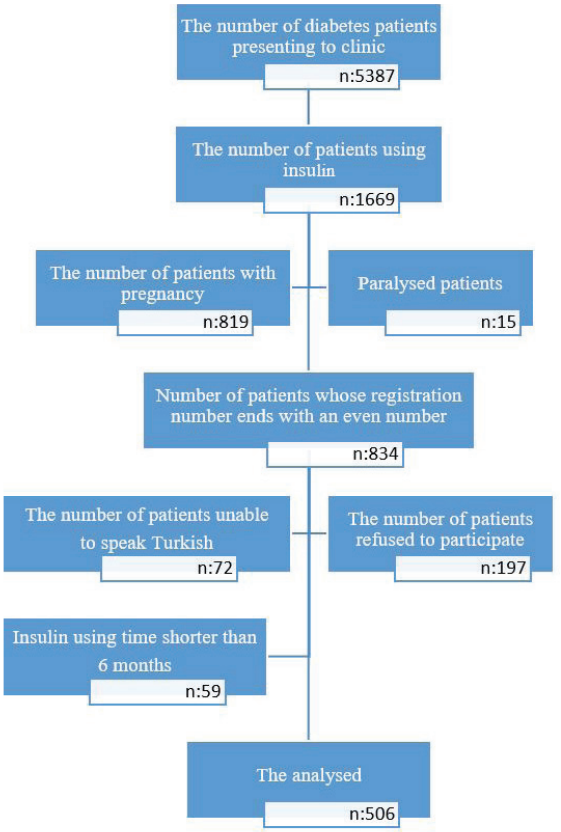

Figure 1: Study flow chart

country would be beneficial to increase the quality of life of diabetic patients. Of the participants 63.4% used smart phone applications. The patient group using smart phone applications were younger, and their BMIs and systolic BP levels were lower. T1DM patients more frequently used smart phone applications as compared with the levels in T2DM patients. The frequency of diabetic complications were lower in these patients, however this difference disappeared in the model which used the age as the confounding factor. The rate of smart phone application use of patients with higher education was found to be 14.7 fold higher compared with the rate in patients with less than primary education; and the rate in patients with income level between 2 to 4 fold of minimum wage was found to be 2.5 fold higher when compared with the rate in patients with an income level of minimum wage and below minimum wage.

Limitations

The patient selection method which minimises the effect of the confounding factors such as age, education status, and diabetes process was not used, therefore this was a factor limiting the study. One another limitation was that the smart applications used by patients could not be detailed.

Interpretations

The diabetes prevalance for all age groups was estimated as 2.8% worldwide in 2000, and the estimates for the year 2030 are 4.4% (9). Type 2 diabetic patients consist the majority of the patients. The USA Center for Disease Control and Prevention report showed that the mean ratios for T1DM, and T2DM in all diagnosed cases were 5.8%, and 90.9%, and the remaining 3.3% group consisted of other diabetes types (10). The reason for the detection of the prevalance of T1DM (22.9%) as higher than the literature in our study group, and less detection of T2DM (77.1%) and other diabetes types was suggested to be due to performing the research with patients who had used insulin.

Various technological devices used by diabetic patients in their daily life were included in the study. The self efficacy of patients who received special messages through a mobile phone significantly improved (11). The motivational effect on the users of a smart phone app developed for diabetic patients was investigated in a study. The software based system which was designed for recording the data of the glucose measurements, pedometer, food habits, and enabling feedback was found successful (12). A similar system was also tested on younger adults. Participants accepted that the use of glucometer was easy, and the system was useful in treatment of diabetes (13). In addition, a meta-analysis investigating 22 studies reported strong evidence that mobile phone directing caused statistically significant improvement in glysemic control, and self efficacy in diabetes care (14). In another meta-analysis, the technological applications were reported to be useful in improving symptom management (15).

The ratio of the smart phone application use of patients was found lower (63.4%) in our study. In addition, 92.5% reported that the patient follow-up system compatible with the smart phone applications specific to our country would be useful. However, none of our participants were detected to have used medical devices associated with smart phones. These results indicated that there was a need for enhancements in motivating the participation of patients to the diabetes treatment, and for development of technological systems.

The comparison of the type 1, and type 2 Diabetes patient groups showed that the patients in T1DM group were younger compatible with the literature (16). This age change contributed to the significant difference in the use of smart phone applications possibly in favor of T1DM patients. In addition, the exercising frequency of the app users might have affected their being more advantageous for microalbuminuria, systolic blood pressure, creatinine, and triglyceride. However, no significant difference was detected for the frequency

Table 2: The comparison of the characteristics of the participants in accordance with the smart phone app use

		The use of smart phone app					
		No		Yes			
		n	%	n	%	χ^2	p
Sex	Male	53	28.6	104	32.4	0.771	0.380
	Female	132	71.4	217	67.6		
DM type	Type 1	9	4.9	107	33.3	53.831	**<0.001**
	Type 2	176	95.1	214	66.7		
DM complication	yes	171	92.4	235	73.2	27.351	**<0.001**
	No	14	7.6	86	26.8		
The use of glucometer at home	Yes	180	97.8	319	99.4	2.396	0.122
	No	4	2.2	2	0.6		
Carrying glucometer with them	Yes-always	36	19.6	112	34.9	20.260	**<0.001**
	Yes-frequently	12	6.5	30	9.3		
	Yes-sometimes	34	18.5	62	19.3		
	No-never	102	55.4	117	36.4		
Aware of e-pulse	Yes	5	2.7	80	24.9	41.456	**<0.001**
	No	180	97.3	241	75.1		
Exercise	Yes	72	38.9	163	50.8	6.637	**<0.010**
	No	113	61.1	158	49.2		
Aware of CH count	Yes	16	8.6	92	28.7	27.996	**<0.001**
	No	169	91.4	229	71.3		
Performing CH counting	Yes	14	56.0	76	73.8	3.049	0.081
	No	11	44.0	27	26.2		
Albuminuria	Normal	33	45.2	88	63.7	6.739	**0.034**
	Micro	30	41.1	38	27.5		
	Macro	10	13.7	12	8.6		
Age group	18-34 years	3	1.6	68	21.2	72.170	**<0.001**
	35-64 years	99	53.5	203	63.2		
	65 years and above	83	44.9	50	15.6		
Educational status	Less than primary education	49	26.5	14	4.4	77.822	**<0.001**
	Primary and secondary education	127	68.6	218	67.9		
	Higher education	9	4.9	89	27.7		
Income level	Minimum wage and less than min. wage	49	26.5	47	14.6	33.556	**<0.001**
	Between minimum wage and 2 fold	105	56.8	144	44.9		
	2- 4 fold of the min. wage	25	13.5	93	29.0		
	Higher than 4 fold of minimum wage	6	3.2	37	11.5		

χ^2: Chi-square test value, DM: Diabetes mellitus, CH: Carbonhydrate

Table 3: Logistic regression computerised outcome

	B	Wald	p.	Exp (B) Lower	95% CI Upper	
Age	-0.068	34.226	**<0.001**	0.935	0.914	0.956
Education status (Reference category: Less than primary education)		28.459	**<0.001**			
Education status (secondary education)	1.241	12.721	**<0.001**	3.458	1.749	6.838
Education status (Higher education)	2.688	28.184	**<0.001**	14.709	5.452	39.687
Income (Reference category: Minimum wage and less)		8.812	**0.032**			
Income (Between Minimum wage and its 2 fold)	0.193	0.418	0.518	1.213	0.676	2.174
Income (2-4 fold of minimum wage)	0.948	6.643	**0.010**	2.580	1.255	5.306
Income (Higher than 4 fold of minimum wage)	0.850	2.015	0.156	2.341	0.723	7.573
Aware of e-pulse (1)	-1.654	10.569	**0.001**	0.191	0.071	0.519
DM type (Type 1 DM)	-0.692	2.403	0.121	0.501	0.209	1.201
Consonant	5.540	59.609	**<0.001**	254.565		

CI: Confidence interval

of the variables of HbA1c, fasting blood glucose, and diastolic blood pressure between patients who used or who did not use the applications. The applications were reported to have an effective component for helping to control HbA1c in type 2 diabetes patients (17). The contradicting of the result in our study with this outcome might be due to having patients who used insulin.

The key to success is providing the use of accurate technological devices, preparing education appropriate for the use of technological devices, and having regular communication with the patient for treatment protocol regulations (18). The results of our study revealed that the application types used by patients were inadequate for directly and significantly contributing in the control of diabetes. The development of technological devices specific to disease (smart insulin pen, noninvasive glucose sensor, insulin pump, various applications, etc) was evaluated to be beneficial for the regulation of diabetes treatment in insulin user patients. The reminder messages, and communication were suggested to be effective for motivating the patient.

Researchers in a study reported that the mean diabetes time was 13.5 years in T2DM patients, and the macrovascular complications in older patients were more common. However, microvascular complications were detected more frequently in patients who were diagnosed with diabetes at a younger age (19). Similarly, the microvascular complication risk in T1DM patients was reported to have increased in a mean of 14 years (20). The results in our study were evaluated as compatible with the literature. The complication detection frequency in younger individuals who used smart phone applications was found lower.

Our study showed that smart phone applications were more frequently used by younger, more educated patients with better economic welfare. In addition, the participants who used more technology were the patients who were more aware of the electronic health register system (e pulse) used in the country. This was compatible with the data in the literature (21, 22). However, the interactions between the investigated variables must be searched with other studies where the confounding effects were minimised.

As Gallagher et al. reported, the possibility of the use of a mobile technology of individuals aged below 56 years was 4 fold higher than the individuals aged over 69 years, and the use of technology owing to the health reasons was 3 fold higher. In addition, researchers reported in the same study that the possibility of using mobile technology high school graduate participants was 2 fold higher than the possibility of individuals who did not graduate from high school, and the possibility of mobile technology use due to health reasons was 5 fold higher (23). Compatible with the previous studies, our study results show an increased 14.7 fold in higher education patients as compared with individuals who did not receive higher education.

CONCLUSION

The frequency of diabetes has been increasing, the treatment costs and the burden in the health system has increased owing to complications emerging after poor follow-up of the disease. In addition, the quality of life, and also the life expectancy of patients have been shortened owing to the complications. Therefore, the development of innovative approaches for patients are important.

In addition, access to the health system, and contact with a diabetes team may be difficult in some pandemia and disaster conditions such as the example of the new coronavirus disease (COVID-19) pandemic caused by the new coronavirus SARS-COV-2. The distant follow-up of patients by physicians with mobile technological applications, the integration of patient measurements, and treatments with the laboratory and outpatient clinic recordings provide an innovative approach for improving diabetes treatment in such conditions.

The use of high level mobile technology must be enabled for diabetes treatment, and preventing complications, must be combined with the appropriate health education, and the patients must be motivated. Considering that our study center is a tertiary care referral institution, the lack of the use of technology of patients is striking. There is an important path to pursue for the integration of the ready for use blood glucose measurement devices and other technological devices in the management of diabetes treatment.

We suggest that there is a need for a system specific to our country for diabetic patients who used insulin, and the interest to this system will be higher in younger educated patients with mid to higher income level.

Ethics Committee Approval: This study was approved by the Clinical Research Ethical Committee of the Istanbul University Istanbul Faculty of Medicine (Date: 10.03.2017, No: 268).

Informed Consent: Written consent was obtained from the participants.

Peer Review: Externally peer-reviewed.

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