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Original Article INTERNAL MEDICINE

The results of following type 2 diabetes patients with mobile health services during the COVID-19 pandemic

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ABSTRACT

OBJECTIVE: The aim of this study is to determine the level of compliance with treatment and achieving metabolic goals in type 2 diabetes mellitus (T2DM) patients who are remotely monitored with mobile health (mHealth) technologies during the pandemic.

METHODS: A total number of 86 patients were included in the study. Data from two periods were used: from 1 month before the date when the first COVID-19 case in Turkiye was reported on March 11, 2020 (Febraury 10, 2020–March 31, 2020) and from the pandemic was severe between April 01, 2020 and May 31, 2020. Participants' mean blood glucose, step count, blood pressure, body weight, and diet compliance levels were evaluated.

RESULTS: When the blood sugar, blood pressure, and weight averages of the patients were compared between the pre-pandemic period and the pandemic months separately, no significant difference was observed. However, it was observed that the number of steps decreased significantly compared to the period before the pandemic ($p<0.05$). It was determined that 88% of the participants were able to access health services without applying to the hospital.

CONCLUSION: In this study, we showed that patients with T2DM who were followed up with mHealth technologies provided the necessary metabolic control and compliance with the treatment during the pandemic.

Keywords: COVID-19 pandemic; diabetes mellitus; mobile health technologies.

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Mobile health (mHealth) is a combination of mobile devices and healthcare. mHealth applications are defined as wireless technologies that are easy to transport and access for both patients and health-care providers and are used to monitor and improve health status [1]. After the widespread use of mobile phones in the past 30 years, thousands of mobile phone-based health projects and hundreds of thousands of smart phone health applications have emerged worldwide [2].

Thanks to the advanced mobile technologies such as Bluetooth, motion detection sensors (accelerometer, gyroscope), global positioning system, and software applications (apps), smartphones present great potential in timing, location, and needs in terms of delivering personalized health-care services. There are many applications developed specifically for diabetes and hypertension [3].

Today, there are many smartphone applications supporting the self-management of type 2 diabetes mellitus (T2DM) and provide daily blood glucose, food intake (including photo recognition), and physical activity tracking, dose recommendation, data transmission, and patient education. As with smart pens, there is a little evidence of controlled operation for these applications.

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Many studies show that mHealth applications raise awareness and bettered the outcomes of patients' body measurements (weight and waist circumference), metabolic and physiological measurements (blood pressure and glucose), safe use and compliance of medications, physical activity, diet management, health conditions and treatment regimens, and their results [4–6].

At the end of 2019, a new coronavirus was detected causing pneumonia cases in China. It spread worldwide and became a global health emergency [7]. The first COVID-19 case in Turkiye was detected on March 11, 2020. The Disease Control Center acknowledges diabetes as an important risk factor for severe COVID-19 disease and mortality [8].

There is a study evaluating mHealth practices in diabetic patients during the COVID-19 outbreak. The study showed that the transition to virtual care models does not limit the glycemic consequences of inpatient diabetes care and should be used to reduce patient and provider exposure in the COVID-19 environment [9].

There has been no study on mHealth applications in our country. Our aim is to determine the treatment compliance and metabolic control levels of T2DM patients who are remotely monitored with mHealth technologies used for the 1st time in our country, and to evaluate the effects of being in this system on patients.

Highlight key points

- This study is the only study conducted in Turkiye, which evaluates T2DM patients with mHealth technologies during the COVID-19 pandemic.
- This work underlines mHealth technologies can provide successful patient's visits by presenting the results of remotely followed patients with chronic diseases who are requiring frequent physician visits.
- Patients in other clinical fields could also be screened effortlessly without time consuming hospital admissions especially in pandemic periods and/or situations where health-care providers (physicians, nurses, and dieticians) are difficult to reach.
- This approach can also be adapted in other clinical fields and in normal time periods even if there is no pandemic or health crisis.
- In the light of this study, health technologies could be used as proven techniques in endocrinology and diabetes researches in the future.

MATERIALS AND METHODS

A total number of 86 patients were included in the study within the scope of Horizon 2020 project ProEmpower–Procuring innovative ICT for patient empowerment and self-management of T2DM, coordinated by Ministry of Health of Turkiye, and funded by the European Commission. The ages of the patients were between 25 and 50. The study was approved by the University of Health Sciences Umraniye Training and Research Hospital Clinical Research Ethics Committee on June 11, 2020 with ethics committee number 231. All patients gave informed consent according to the Institutional Review Board guidelines and the Declaration of Helsinki.

Data from two periods were used: From 1 month before the date when the first COVID-19 case in Turkiye was reported on March 11, 2020 (February 10, 2020–March 31, 2020) and from the pandemic was severe between April 01, 2020 and May 31, 2020.

The average blood glucose, step count, weight, and blood pressure measurements of the patients were recorded day by day using mobile phone technologies. Two software applications called MetaClinic and DM4All were used as a virtual monitoring system for diabetes in our study.

The 4-month metabolic averages of each patient were calculated. The capillary glucose levels of the patients, the number of steps, systolic and diastolic pressures, body weights, and dietary compliance levels were followed and evaluated. In addition, the patients were compared with themselves and with other patients by month.

Blood pressure and fingertip capillary glucose measurements were performed with Medisante BP800 3G Blood Glucose Plus Blood Pressure Monitoring System (Taiwan, 2019), Beurer BM77 (Germany), and Accu-Chek Instant (USA). Medisante BC800 3G (Taiwan), and Beurer BF600 (Germany) were used for weight tracking, and Garmin Vivosmart 4 and XiaomiMi band 3 smart watches were used for step counts. In addition, XiaomiRedmi 6A (China, 2019) and UMIDIGI A3 (China) brand smart phones were also given to the patients, which both provided the synchronization of the given devices with each other with Bluetooth ability and used the DM4All and MetaClinic tracking system.

In addition, a 9-question questionnaire was applied to evaluate the impact of the pandemic on patients. The data were collected by calling the patient on the phone. The questionnaire included: The emotional state when the corona outbreak started, the effect of corona measures on diabetes, the ability to reach the doctor without going to the hospital whenever the patient wants, the control and examination disruption during the pandemic, the opinion about the mHealth services given, the

Table 1. Monthly comparative blood sugar average, systolic blood pressure, diastolic blood pressure, step average, and weight average data

	February	March	April	May	March/ February	April/ February	May/ February
Blood glucose (mg/dl) Mean±SD	160.36±55.83	154.74±56.22	158.01±59.91	140.92±45.41			
Z*					-1.625[b]	-0.171[b]	-1.815[b]
p value					0.104	0.864	0.070
Systolic blood pressure (mmHg) Mean±SD	124.22±19.71	122.01±15.05	120.51±15.19	119.85±12.33			
Z					-0.011[b]	-0.363[c]	-0.031[b]
p value					0.991	0.717	0.975
Diastolic blood pressure (mmHg) Mean±SD	78.98±12.22	77.45±10.55	76.28±9.88	76.38±9.72			
Z					-0.105[b]	-0.883[c]	-0.526[c]
p value					0.916	0.377	0.599
Step count/day Mean±SD	6.358±3.741	5.805±3.591	4.367±3.223	4.683±2.817			
Z					-2.226[b]	-5.237[b]	-3.907[b]
p value					0.026	0.000	0.000
Body weight (kg) Mean±SD	87.36±15.68	85.21±16.01	86.27±17.37	86.58±15.27			
Z					-1.562[b]	-0.034[c]	-1.200[b]
p value					0.118	0.973	0.230

*: Z score; SD: Standard deviation; a: Wilcoxon Signed Ranks Test; b: Based on positive ranks. c: Based on negative ranks.

effect of the COVID-19 pandemic on individuals with chronic diseases, whether they or their relatives caught COVID-19 disease, whether they would like to benefit from non-diabetes mHealth services, and how they solved the problems in any health-related complaint during the pandemic period.

Statistical Analysis

Statistical Package for the Social Sciences (SPSS) Mac Version 21 (SPSS Inc. Chicago, IL, USA) software program was used to evaluate the research data. Descriptive statistics were presented as numbers and percentages for categorical variables, and mean, standard deviation, and median for numerical variables. Homogeneity was performed according to Levene's test and $p>0.05$ was evaluated as homogeneous.

Testing for the distribution of continuous variables to normal was evaluated with Kolmogorov–Smirnov normality $p>0.05$ or Skewness-Kurtosis test, and it was accepted as normal distribution in the range of ±1.5. Paired t-test and Wilcoxon signed rank-sum test were used to measure the difference between baseline and final values. Significance was evaluated at $p<0.05$ for all values.

Table 2. HbA1c level before and after the pandemic

	HbA1c (%)
Before the pandemic	7.8
After the pandemic	7.4
p*	0.02

*: P-value.

RESULTS

The averages of blood glucose, systolic, and diastolic blood pressure of the patients from 1 month before the pandemic and from the 3-month pandemic period are summarized in Table 1.

No significant difference was observed in blood glucose levels of the patients between February, which is the pre-pandemic period, and the 3-month period (March, April, and May) of the pandemic period (Table 1).

When the pre-pandemic period and post-pandemic HbA1c levels were compared, a significant decrease was observed (Table 2).

When systolic and diastolic blood pressures were compared, no significant difference was found between the pre-pandemic period and the pandemic period (Table 1).

The mean step of the patients before the pandemic period was 6338±3741 and it decreased significantly during the pandemic period (Table 1).

When we compared the body weight averages of the patients in February, March, April, and May, no statistically significant difference was found in weight gains during the pandemic period (Table 1).

Questionnaires were applied by phone to 80 people in the group of 86 people in the study. The answers of the participants in the study are shown in Table 3.

A total of 80 people participated in the survey. In the first question, since the corona epidemic started, 46.25% of the patients stated that they felt the same, 40% worse and 13.75% felt better.

When we asked the second question which was how corona measures affected the patients with diabetes disease, 47.5% said that it did not change, 42.5% was negatively affected and 10% positively affected. The negatively affected patients (42.5%) stated that they could not do physical activity and experienced psychological problems. On the other hand, 47.5% of the participants stated that their follow-up continued thanks to the application.

In the third question, accessibility to health services/doctor without applying to the hospital was positive with 88% thanks to the application.

The fourth question was, "Did the corona pandemic reduce your controls and examinations in the hospital?" 61% of people answered yes.

In the fifth question about the emotional state of the patients using the mHealth system during the pandemic period, 90% of the patients said that they felt safe in this system.

TABLE 3. Survey questions and answers of the participants

		Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8	Option 9	Option 10
		f	%	f	%	f	%	f	%	f	%
Valid											
Q1*	11	**13.75**	32	**40**	37	**46.25**					
Q2	8	**10**	34	**42.5**	38	**47.5**					
Q3	71	**88.75**	2	**2.5**	7	**8.75**					
Q4	49	**61.25**	31	**38.75**							
Q5	72	**90**	–	–	5	**6.25**	3	**3.75**			
Q6	51	**63.75**	16	**20**	13	**16.25**					
Q7	1	**1.25**	–	–	57	**71.25**	22	**27.5**			
Q8	27	**33.75**	48	**60**	5	**6.25**					
Q9	7	**8.75**	9	**11.25**	17	**21.25**	31	**38.75**	16	**20**	
Total											80
Missing system											6
Total											100.0

f: Frequency; *: Question.

In the sixth question about whether the corona epidemic affects individuals with chronic diseases, 63% of patients said that they were affected more.

The seventh question was answered no by 71% of the patients, in response to "Are there individuals around you who are corona positive?"

The eighth question was "Did you benefit from mHealth services during the pandemic period for your complaints other than diabetes?" 33% of the participants stated that they benefited and contacted the mHealth team and 60% of those involved stated that they did not think about it, and they would be pleased if such an application could be provided.

The last question was about which method they used to deal with disease and complaints during the pandemic period. About 38% of the participants contacted the mHealth practice physician, 20% had no problem, 8% of the participants applied directly to the upper-level health institutions, and 21% of them applied to their family physician.

DISCUSSION

In this study, 86 patients diagnosed with T2DM were examined. Patients were followed up with the mHealth system during the COVID-19 outbreak. Our study aimed to evaluate metabolic control of patients with T2DM followed remotely with mHealth services during the pandemic, their compliance with treatment, and the effect of this system on patients.

In this study, we have shown that patients with T2DM who are followed up with mHealth technologies provide the necessary metabolic control and compliance with the treatment during the pandemic. Continuing uninterrupted health-care services thanks to mHealth applications prevented deterioration in metabolic control. In this study, it was observed that the exercise adaptation of the participants was not at the desired level due to the pandemic. According to the results of the survey, a great majority of the participants thought that being able to access health services without leaving home positively affected them. The fact that patients are being monitored remotely during the pandemic has allowed the continuation of the critical medical support for these patients and the protection of patients in high-risk groups such as diabetes. Remote monitoring with mHealth technologies has been a successful method in the pandemic in patients with T2DM.

Recent advances in mHealth have created new opportunities to improve self-management of diabetic patients with tools facilitating access to information on healthy eating, exercise, and healthcare. This innovative model includes integrated systems connecting patients to support networks through mobile smartphones [10].

However, to date, there is little research focusing on how technology can be used to expand the support network of smartphone apps for T2DM patients. A recent systematic literature review reported that more clinical trials are needed to examine the effect of mHealth technologies on diabetes and hypertension [11].

In an internet-based, diabetes self-management project called the diabetes network (D-Net) by Glasgow et al. [12] the diet, exercise, and risk factors of 320 patients were evaluated for 10 months. It has been shown that all outcomes related to behavioral, psychosocial, and some biological results improved significantly compared to the beginning.

An important part of chronic disease management is to ensure adequate patient-physician relationship. As a matter of fact, in the study conducted by Lim et al. [13] on Latin Americans, it was concluded that as the relations of patients with their physicians increased, they performed the recommended exercises more and this adherence increased the level of physical-mental health. Similar to the previous studies, our study showed that the participants' diet and medication compliances were facilitated by virtually being able to reach the physician continuously, and the participants who were constantly monitored by the physician felt themselves psychologically safe.

Lifestyle and behavioral changes are essential components of diabetes management, especially T2DM. Many studies have shown that lifestyle modification is beneficial in disease management, improving glycemic control, and reducing diabetes-related complications [14].

McKay et al. [15] tested the use of an internet-based application to increase the level of physical activity in patients with T2DM. The study consisted of 78 participants and lasted for 8 weeks. It was found that there was an overall moderate improvement in physical activity levels in both the intervention and control groups, but no significant improvement in terms of state effects. While there was a significant difference in diet and psychosocial aspects, it was observed that the treatment results did not change.

In the study conducted by McIlhenny et al. [16], diet, exercise, medication compliance, and the number of steps

were evaluated by making a comparison with the control group. It was observed that diabetes education/knowledge increased in the group participating in the study and the frequency of glucose measurement increased, but there was no difference between the groups.

In our study physical activity tracking was carried out with the number of steps, which supports these studies. Due to the pandemic, patients could not reach the 10,000-step target. As expected, the number of steps decreased significantly during the pandemic period due to the restrictions. Although the number of steps of the patients decreased, the lack of significant weight gain was thought to be a result of compliance with medications and diet.

In a study conducted by Noh et al. [17] in 2010 with 40 participants (20 in control group and 20 in experimental group), HbA1c and blood glucose levels were monitored for 6 months, and it was observed that HbA1c and postprandial glucose levels decreased significantly in the control group over time. In addition, a significant relationship was found between the change in HbA1c and the frequency of accessing the mHealth system through mobile phone.

Similarly in our study, the blood glucose and HbA1c levels of the patients were monitored. During the epidemic, it was observed that there was no deterioration in the blood sugar regulation of the patients, and there was a decrease in the HbA1c values after the pandemic. Thus, it was determined that the follow-up of the patients could be done through the mHealth system and further this sensitive population was protected from epidemic diseases.

In our study, the fact that the participants stayed in contact with the mHealth physician virtually facilitated diabetes self-care and diabetes management. Thus, there was no problem in compliance with the treatment.

A study was conducted by Carter et al. [18] in 2011 in African Americans over the age of 18, with a total of 47 people (26 people in intervention group and 21 people in the control group) who received random treatment with a telehealth system. In this study, the target was determined as Hba1c ≤7.0% (53 mmol/mol) and BMI <25. The probability of reaching the desired HbA1c target was found to be 4.58 times higher for the group monitored by the telehealth system. However, a significant positive relationship was found between the participants' reaching the target BMI and using the health service. No such relationship was found between being in the treatment group and maintaining 130/80 blood pressure.

In our study, it was observed that there was no deterioration in blood sugar and blood pressure regulation and there was a significant decrease in HbA1c levels by monitoring the participants remotely during the pandemic period. Although there was a significant decrease in the number of steps due to the pandemic, weight increase was not observed. In addition, it has been determined that the participants constantly monitored by the physician feel themselves psychologically safe.

Unlike other studies, the participants were surveyed by phone about their diabetes knowledge level, compliance with diabetes management behaviors, and the pandemic period. According to the survey results, patients felt safe during the COVID-19 pandemic as their medical follow-up continued thanks to mHealth. COVID-19 did not develop in any of the patients followed during this period.

To the best of our knowledge, our study is the only study that closely monitors and evaluates blood glucose, blood pressure, physical activity (number of steps), and weight values of patients with diabetes who are followed up with mHealth services during the pandemic period. In addition, it is an especially important study since it is the first study in which mobile technologies are used in our country.

However, the weakness of this study is that it was conducted in a small patient group and there was no control group. A control group was not included due to the risk of exposure during the pandemic.

The fact that our patient group consisted of patients with no diabetes complications (micro and macro complications) and younger (25–50 years old) patients may have enabled comparatively better compliance and reaching our metabolic control goals more easily. On the other hand, in line with corona measures, lack of physical activity (sedentary life) and psychosocial traumas caused by the pandemic are factors that will cause difficulties in blood sugar regulation.

In conclusion, despite the limitations of our study, it is thought that it will make important contributions to the literature. The first contribution of the study is that the most important factor affecting compliance with treatment in diabetes is the importance of constant communication between the patient and the physician. The second most important contribution is that during pandemic periods and/or situations where health-care providers (physicians, nurses, and dieticians) are difficult to reach, the use of mHealth services in patient

and disease management effectively helps health-care managers and health-care professionals combat diseases and pandemic.

Conclusion

Type 2 diabetes is a serious public health problem and requires regular treatment. Therefore, it is of great importance for diabetic patients to benefit from health-care services. Successful diabetes treatment includes the self-management of the diabetic patients and delaying or preventing complications and comorbid diseases. Based on findings from major clinical trials and professional guidelines, diabetes education programs and health-care providers include daily blood glucose monitoring, healthy eating, stress management, medication compliance, and physical activity regimens. Adherence to regular and long-term regimes is difficult.

mHealth practices are increasingly being used to assist with lifestyle changes and patients with diabetes' self-management among health-care providers. The effectiveness of mHealth to improve diabetes outcomes depends on patient interaction with technology, content, and providers.

In cases where it is difficult to reach healthcare workers, such as during the pandemic period, the use of the mHealth systems allow the patient to continue treatment and provide metabolic control. Based on the results of this study, it is possible to provide an effective mHealth support during the pandemic period in diabetes.

Ethics Committee Approval: The University of Health Sciences Umraniye Training and Research Hospital Clinical Research Ethics Committee granted approval for this study (date: 11.06.2020, number: 231).

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