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Telemedicine in the Management of Patients with Diabetes Mellitus Results of an 18-Month Follow-Up

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ABSTRACT

Introduction: Increasing number of patients with type 2 diabetes mellitus places growing demands on patient management. Addressing this issue requires the integration of innovative technologies, including telemedicine. Parameters can be measured in a home environment (self-monitoring of blood glucose, blood pressure, ecg, weight, oximetry, spirometry) by the patients themselves, with the data transmitted via suitable technology.

Methodology: Prospective, Non-Interventional, Clinical Study Conducted Under Routine Clinical Practice Conditions In a Diabetology Outpatient Clinic.

Results: A total of 216 patients were included in the telemedicine follow-up: 109 women (51.66%) and 102 men (48.34%). The average usage duration of the telemedicine kit was 8.8 months. Postprandial blood glucose levels showed the greatest improvement after six months of intervention; over time, glucose levels slightly increased but remained below baseline values. HbA1c levels (baseline 7.83% DCCT) improved initially (6.85% DCCT) and remained in the optimal range for 18 months. Among telemedicine kit users, 42.5% achieved HbA1c < 7% DCCT, while 23.3% had HbA1c > 9% DCCT. Women experienced greater weight reduction (from 85.30 kg to 84.0 kg, -1.53%) compared to men (from 98.26 kg to 97.46 kg, -0.83%). Blood pressure was the most frequently monitored parameter, with most patients maintaining values within the optimal range.

Conclusion: The transmission of data allows physicians to actively adjust treatment and recommendations without the immediate need for in-person visits, thereby reducing the time required for making relevant medical decisions and implementing them for patients.

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Introduction

Type 2 diabetes mellitus (T2DM) is a lifelong, chronic progressive disease with increasing prevalence and incidence. T2DM has not only a healthcare dimension but also a societal, economic, social, and family impact, directly affecting the patient's quality and length of life. The disproportion between the number of healthcare providers and the growing number of T2DM patients places increased demands on patient management. Solutions require a multifactorial approach involving innovative technologies. Telemedicine is one of the solutions that can be easily implemented into clinical practice [1]. Telemedicine is the provision of healthcare services where distance is a critical factor, by all healthcare professionals using information and communication technologies to exchange relevant information for diagnosis, treatment, and prevention of diseases and injuries, research and evaluation, and for the further education of healthcare providers, all with the goal of improving the health of individuals and their communities. The World Health Organization (WHO) published recommendations for the implementation of telemedicine in 2022 [2].

Treatment Goals for Type 2 Diabetes Mellitus

The primary objective of type 2 diabetes mellitus (T2DM) treatment is to optimize metabolic compensation through both pharmacological and non-pharmacological approaches to slow the progression of microvascular and macrovascular complications. The goal is to achieve target fasting and postprandial blood glucose levels, maximize time spent within the optimal glycemic range, minimize the risk of hypoglycemia and hyperglycemia, reduce body weight, and regulate blood pressure within target values.

As the disease progresses, changes in the patient's age, the presence of complications, and comorbidities affect their overall health and adherence to treatment. Therefore, a personalized therapeutic approach is required for each patient with T2DM, involving continuous adjustments to treatment, goals, and priorities.

The gold standard for assessing metabolic compensation is glycated hemoglobin (HbA1c). HbA1c values are expressed as a percentage according to the DCCT (Diabetes Control and Complications Trial). In well-controlled patients (HbA1c < 7.3% DCCT), postprandial glycemia contributes the most (70%) to the final HbA1c value. When HbA1c levels exceed 8.3%, persistent hyperglycemia has a predominant influence.

The Role of Telemedicine in Managing Patients with Diabetes Mellitus

The treatment of type 2 diabetes mellitus (T2DM) consists of both non-pharmacological and pharmacological approaches. Measurable parameters of patient adherence to treatment include self-monitoring of blood glucose (SMBG), blood pressure measurement, changes in body weight, and the objective indicator of glycated hemoglobin (HbA1c) [3,4]. In critical situations, electrocardiogram (ECG) recording and evaluation are considered essential examinations. Currently, it is possible to monitor oxygen saturation at home using an oximeter. These parameters can be measured by the patient in their home environment. If devices capable of transmitting measured data to a physician are available, treatment strategies and recommendations can be actively adjusted without the immediate need for an in-person visit to a healthcare facility. This reduces the time required for relevant medical decision-making and its implementation by the patient [5]. With the use of telemedicine, self-monitoring of blood glucose (SMBG) can be effectively evaluated, as it is available to all patients with diabetes mellitus (DM). Structured SMBG is essential for improving long-term glycemic control (HbA1c). The effectiveness of SMBG increases with real-time availability [6]. Home blood pressure monitoring is one of the most effective methods for controlling hypertension, allowing for therapy adjustment and personalization [7,8]. Regular weight monitoring is an important indicator of adherence to dietary and lifestyle measures in T2DM treatment [9]. Patients with T2DM are more motivated to lose weight immediately after diagnosis. This initial treatment window provides an opportunity to enhance motivation for weight reduction. Approximately 15% of patients with T2DM have atrial fibrillation (AF). If AF occurs in patients with T2DM, heart failure is highly likely to develop, and it is an independent risk factor for thromboembolism and stroke [10,11]. A telemedicine kit containing an ECG device allows for the detection of newly developed atrial fibrillation episodes as well as other arrhythmias. Risk factors that increase the likelihood of sudden coronary death (SCD) in patients with T2DM include silent myocardial ischemia, autonomic dysfunction, abnormal repolarization, nocturnal hypoglycemia, hypercoagulability, diabetic cardiomyopathy, and hypoxia with hypercapnia related to concurrent respiratory insufficiency. In patients with acute or exacerbated chronic respiratory disease, oxygen saturation measurement with an oximeter is recommended. Commercially available oximeters provide relevant information on blood oxygen saturation [12].

Study Population and Methods

In a prospective, non-interventional clinical study conducted under the conditions of routine clinical practice in a diabetology outpatient clinic, we monitored 216 patients with T2DM who were willing to participate in the study, undergo repeated measurements, and regularly submit recorded data. Approximately 25% of the approached patients declined to participate in the study. The monitoring was conducted from 1.6.2022 to 31.12.2023. Patients attended regular visits to the outpatient clinic, with varying intervals between visits.

The primary objective of the study was to evaluate the achieved metabolic compensation in patients who, in addition to routine clinical practice, used the Telemon® telemedicine kit. The secondary objective was to assess the willingness for long-term cooperation, the frequency of self-monitoring, and the usage frequency of individual components of the telemedicine kit during the observation period. The composition of the telemedicine kit and the types of devices are listed in Table 1.

Table 1: Composition of the Telemedicine Kit

Measuring Device		Type
1.	Glucometer	FORA Diamond MINI DM30
2.	Weight	Xiaomi Mi Body Composition Scale 2
3.	Pressure Gauge	G.LAB MD4781
4.	Thermometer	Rycom JXB 182B
5.	EKG	EKG Monitor Prince 180B
6.	Oximeter	ChoiceMMed MD300C228
7.	Spirometer	Contec SP80W
8.	Mobile HUB	Samsung A12

We also verified the time interval from measurement using an interoperable device to the transmission of data from home monitoring of the observed parameters. After signing the informed consent, each patient was provided with a complete telemedicine kit with devices, as listed in Table 1. All devices were equipped with Bluetooth technology, which enabled automatic transmission of measured values to the server, allowing healthcare personnel direct real-time access to the data.Each diabetic patient was educated on the correct use of each device, the proper measurement of monitored parameters, and data transmission. Patients sent their data via the Telemon® portal. Each patient had a separate anonymized account, logging in with their chosen username and password. During in-person visits, all standard examinations were performed, including HbA1c evaluation.

The Results

The dataset contains measured data recorded from June 8, 2022, to December 31, 2023. We evaluated the measurements from the utilized devices. The duration of monitoring varied among patients. The data analyzed in this study were complete, with no measurements removed.The evaluated parameters included the number of glucose measurements, average fasting and postprandial glucose levels, glycemic variability, changes in HbA1c, body weight, blood pressure, pulse rate, and the use of other devices such as ECG, spirometer, and pulse oximeter (Table 1). The data were statistically processed using the t-test, F-test, and χ^2 test. Results are presented as mean [+SD (standard deviation)], numbers, or ratios. A Kaplan-Meier survival analysis was performed for the monitored patients.

Descriptive Statistics of the Dataset

The analyzed dataset consisted of 216 patients, including 109 women (51.66%) and 102 men (48.34%). The average age of the entire patient group was 59 years, with women averaging 62 years and men 57 years.During the monitoring period, the number of patients varied. Seven patients returned the set within the first week. The average duration of kit usage was 8.8 months.

Analysis of Glycemia

Blood glucose levels were measured using the FORA Diamond MINI glucometer. We analyzed the glycemic profile of capillary blood samples during the initial self-monitoring (first day), recorded in five time segments: fasting, post-breakfast, post-lunch, post-dinner, and nighttime glucose levels. After adjusting post-lunch and post-dinner glucose levels, the most significant improvement was observed after six months of intervention. Over time, glucose levels slightly increased but did not exceed baseline values (Figure 1).

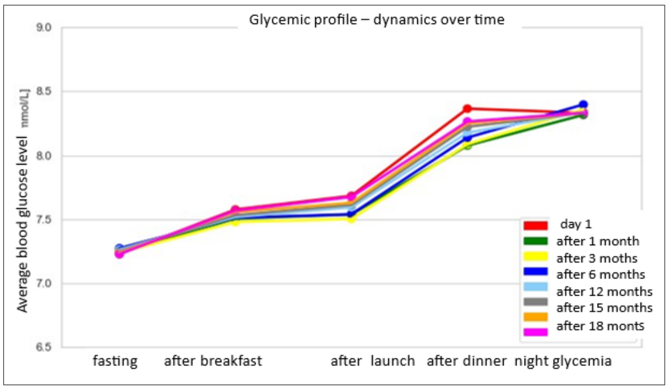

Figure 1: Glycemic Profiles of the Dataset Based on the Time Period Since the Start of Measurement

Glycosylated Hemoglobin (HbA1c)

The goal of the analysis is to highlight the change in HbA1c as an indicator of long-term metabolic control during the patient's outpatient visits. Metabolic compensation (initial value 7.83% DCCT) showed an initial improvement (6.85% DCCT) and was maintained within the optimal range for the entire 18-month evaluation period (Figure 2). No significant differences were observed between genders (Figure 3). When using the telemedicine kit, 42.5% of patients achieved optimal metabolic compensation (HbA1c < 7% DCCT), while 23.3% of patients had inadequate compensation (HbA1c > 9% DCCT) (Figure 4).

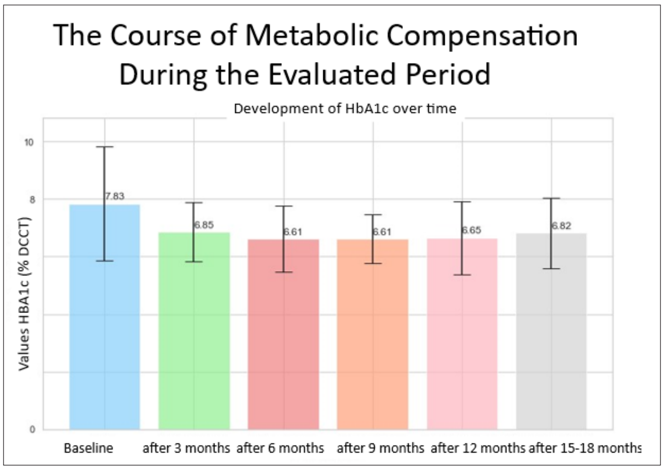

Figure 2: Course of Metabolic Compensation During the Evaluation Period

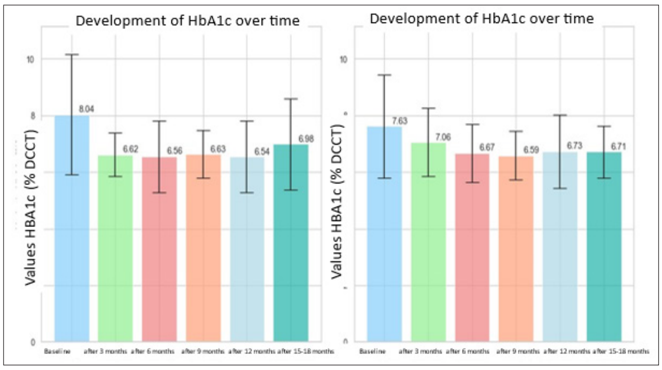

Figure 3: HbA1c Values in Selected Time Intervals (Women, Men)

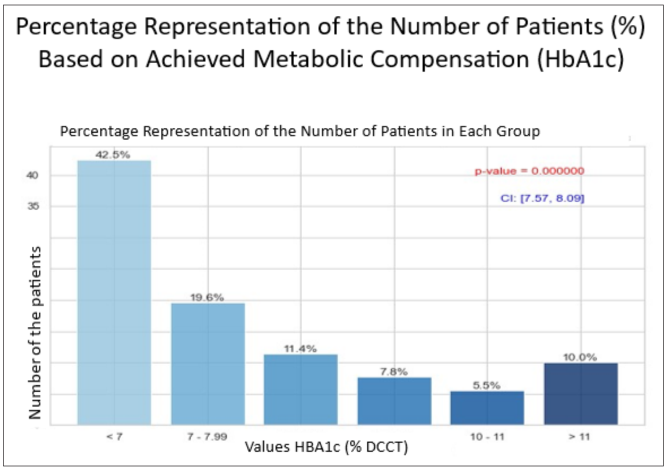

Figure 4: Percentage Distribution of Patients According to Achieved Metabolic Compensation (HbA1c)

Weight Analysis

Weight was measured using the Mi Body Composition Scale 2 digital scale. The goal of the analysis was to express the percentage change in patients' weight over the course of visits, from the start of measurement to the end of the observation period. For women, the weight decreased from 85.30 kg to 84.0 kg, showing a greater reduction compared to men, whose weight decreased from 98.26 kg to 97.46 kg, representing a -1.53% versus 0.83% change. Neither group achieved the optimal weight loss target (-5%).

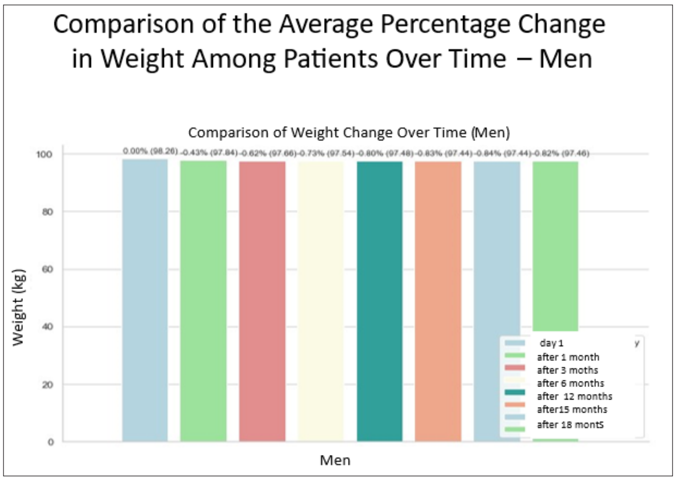

Figure 5: Comparison of the Average Percentage Change in Weight Over Time for Male Patients

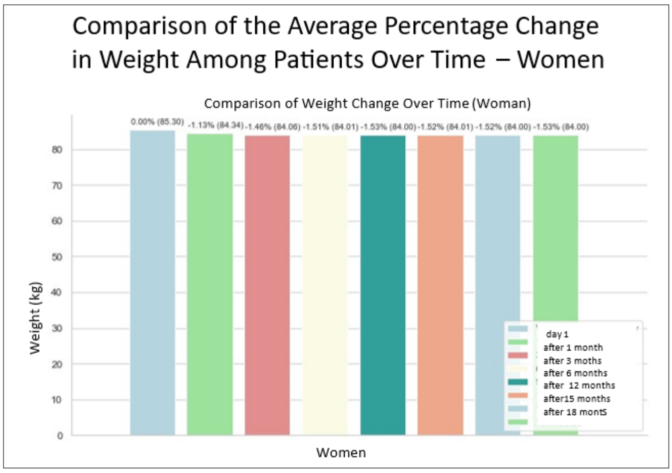

Figure 6: Comparison of the Average Percentage Change in Weight Over Time for Female Patients

Blood Pressure Analysis

Blood pressure (systolic and diastolic) and pulse rate were measured using the G.LAB DIGITAL AUTOMATIC Blood Pressure Monitor (MD4781). The goal of the analysis was to track the changes in systolic and diastolic blood pressure during treatment, similar to the self-monitoring glucose (SMG) measurements. The analyzed blood pressure values suggest that the most significant change occurs between the first measurement and the measurement after one month. Blood pressure in most patients showed optimal values. The upper range of measured blood pressure indicates groups of patients with inadequate blood pressure control. A significant difference in measured blood pressure between male and female groups was not observed.

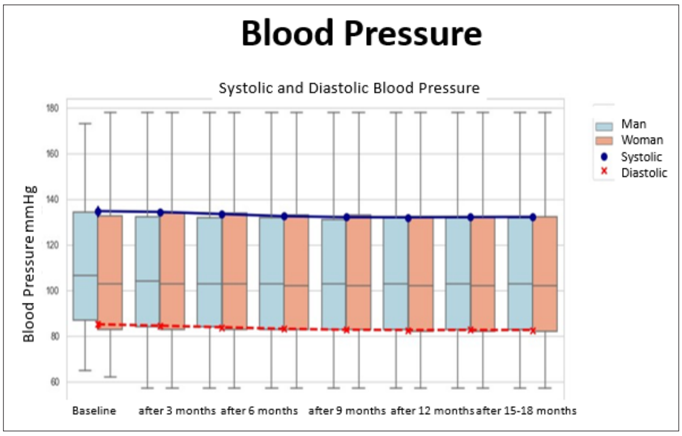

Figure 7: Comparison of Blood Pressure Over Time – Men vs. Women

Data Transfer Time from Interoperable Measuring Devices

The Telemon® solution provides several benefits. One of the key benefits is the rapid transmission of measured data from home monitoring of vital functions to the Telemon® platform. A critical benefit identified was the increased utilization of measured data in providing healthcare, thanks to the quick accessibility of patient vital function data obtained from interoperable medical devices or manually entered by the patient. We monitored the time taken for the platform to reliably ensure data transmission after measurement with interoperable devices. In the first evaluation period (June 1, 2022, to April 30, 2023), the highest data transmission occurred within 30 seconds of being measured by the patient, followed by transmission within 1.5 minutes (Figure 8).Figure 9 shows the percentage of patients with data transmission within 2 minutes.

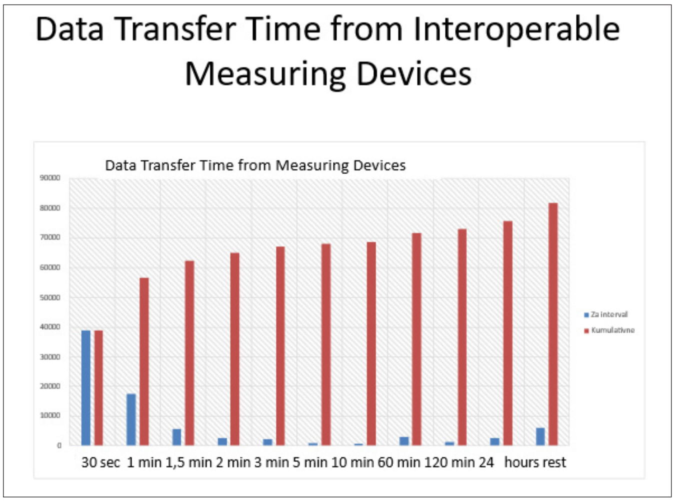

Figure 8: Data Transmission Time from Interoperable Measurement Devices

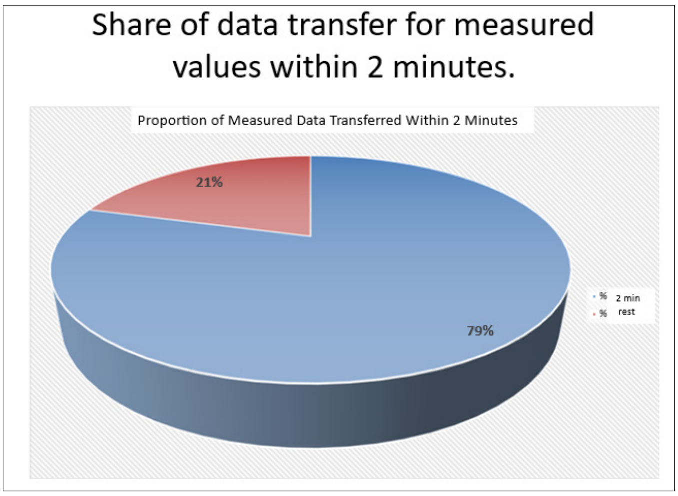

Figure 9: Percentage of Data Transmission Within 2 Minutes

Delays longer than 2 minutes are typically caused by unavailable internet connections or incorrectly set device times. The greatest delays were recorded when using the spirometer, blood pressure monitor, and glucometer. These data need to undergo further analysis to identify the reasons behind these anomalies. One potential cause could be application "fixes" or the small sample size of patients. A future challenge will be ensuring that devices are capable of remotely setting the time, to avoid issues related to daylight saving time or incorrect manual time settings.

Use of Other Measuring Devices

In addition to the blood pressure monitor, glucometer, and scale, the patients involved in the study also had access to other devices. These measuring devices include:

- **Spirometer:** CONTEC SP80B
- **Pulse Oximeter:** OxyWatch FINGERTIP
- **ECG Monitor:** Heal Force Easy ECG Monitor
- **Thermometer:** Berrcom Non-contact Infrared Thermometer JXB-182B

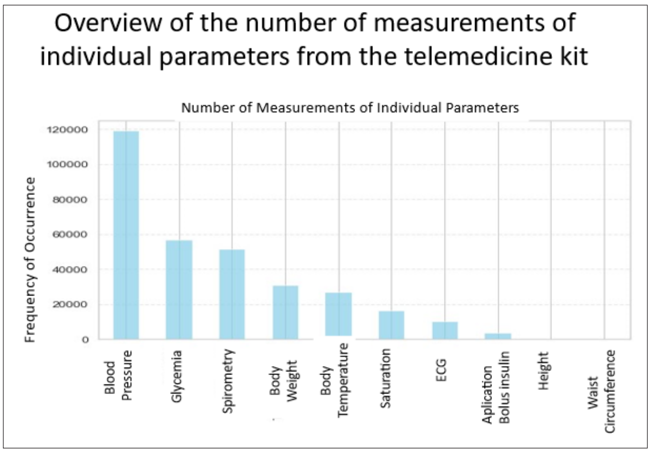

Figure 10: Overview of the Number of Measurements for Each Parameter from the Telemedicine Kit

Discussion

Telemedicine in diabetology involves the use of telecommunications technologies and digital tools to provide care and support to patients with diabetes remotely. Using these technologies, individual parameters essential for disease management are monitored online, leading to improved healthcare through recommendations for adjusting medication therapy, monitoring, and managing lifestyle habits. In critical situations, it contributes to quick diagnosis and management of health problems [13]. Most recently published studies focus on managing patients through telemedicine during the COVID-19 pandemic. These works evaluate the frequency of contacts, the geographical coverage of telemedicine centers, and the significance of contacting patients through telemedicine technologies. Only a few studies provide quantitative indicators observed during telemedicine patient monitoring [14]. The contribution of our study lies in the recording of quantitative parameters indicating disease compensation and vital functions of the patient over an 18-month period in the longest-followed patients. Type 2 diabetes (DM2T) is a long-term chronic condition, during which cooperation in disease management tends to decrease over time. Compliance with medication usage, especially in polypharmacy, declines. Non-adherence to medications is often only discovered retrospectively, most commonly when evaluating laboratory results. As the disease progresses, the frequency of self-monitoring of blood glucose also decreases, even among patients for whom self-monitoring of glucose (SMG) is an essential part of disease management, including insulin therapy adjustments. Based on the number of measurements in our cohort, we observe that patients with DM2T measure their blood pressure more frequently than monitor their blood glucose, which is consistent with expectations, as patients treated with oral antidiabetic drugs (OAD) are provided with 50 glucose measurements over a 4-month period by public health insurance. Patients monitored through telemedicine maintain long-term optimal metabolic compensation throughout the entire 18-month observation period. Telemedicine is part of the therapeutic intervention. Its impact on the achieved HbA1c value cannot be quantified. However, we can assume that continuous monitoring contributes to increased adherence to medication therapy as well as to the non-pharmacological aspects of treatment. During the monitoring of patients, optimal blood pressure values were achieved. The upper limit of the interval indicates that some patients required an adjustment of blood pressure medication during the observation period. The upper boundary of the measured values remained unchanged, which requires further analysis. Patients in the observed cohort achieved a reduction in body weight, but without reaching the 5% weight loss target. This confirms that further intervention focused on weight management is needed, as shown in studies like Direct [15]. A limitation of the set is the lack of a pedometer. Telemedicine allows for the diagnosis and monitoring of chronic complications, including the sharing of symptoms, test results, and photographic records [16]. Despite the advantages of telemedicine in long-term care, several barriers exist that may limit its effectiveness, such as the acceptance rate of the technology, mental well-being while using it, and the skill level in operating telemedicine devices. During the study, 25% of patients rejected the telemedicine kit. The results confirm the need for continuous communication with patients as part of the intervention. The technology alone, without communication, leads to a decrease in the frequency of monitoring and, consequently, the effectiveness of the intervention. Additionally, collaboration between physicians, educators, and telecommunication service providers is necessary [17]. The risks associated with the application of telemedicine include the significant limitation of physical examinations of patients. A risk also exists due to differing understandings of the technology by either the physician or the patient. When transmitting unsecured data, there is a risk of breaching confidentiality. There is also a risk to the integrity and availability of all relevant health information if communications are not recorded in the health documentation. For some patients, telemedicine is inaccessible due to technical knowledge, particularly for seniors and marginalized groups of patients [18-20]. Telemedicine in diabetology can be particularly useful for patients living in remote areas, with limited mobility, or those in need of regular medical care. It is also beneficial in cases where the demand for examinations exceeds the capacity of healthcare facilities, or when the frequency of examinations as per clinical guidelines is not in line with what is accepted by health insurance companies. However, it is important to remember that telemedicine does not replace all aspects of traditional medical care and should be used in appropriate situations. The doctor will always assess whether telemedicine is suitable for a specific patient and their healthcare needs.

Conclusion

In the management of patients with diabetes mellitus (DM), tools are needed to objectify the state of metabolic compensation and vital functions. Based on the obtained results, it is possible to evaluate treatment goals, the prognosis of complications, adherence, compliance, and continuous patient motivation.

The basic research was conducted with the help of telemedicine kits capable of monitoring the parameters tracked in the management of type 2 diabetes (DM2T), which represents an innovative and original way to reduce the frequency of patient visits to diabetology clinics, while ensuring the quality of healthcare delivery. At the same time, the workload on healthcare staff is reduced, as the telemedicine system and appropriate components enable continuous monitoring of the tracked patients, and technical support for telemedicine services can also be incorporated into the healthcare system. The benefit of the study is its feasibility in the context of regular clinical practice in healthcare for patients with DM2T.

Acknowledgment

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