INFLUENCE OF BEHAVIORAL RISK FACTORS ON GLYCEMIC CONTROL IN PATIENTS WITH TYPE 1 DIABETES

Donika Kandilarova

Department of Social Medicine and Healthcare Organization,
Faculty of Public Health, Medical University of Varna, Bulgaria

Abstract

Introduction: Behavioral risk factors, such as nutrition, physical activity (PA), and perceived stress levels in daily life, have a significant impact on glycemic control in patients with type 1 diabetes mellitus (T1DM). Despite advances in insulin therapy and monitoring technologies, unhealthy habits continue to hinder effective treatment.

Aim: The aim of the present study was to assess the influence of the main components of lifestyle on glycemic control in patients with T1DM.

Material and methods: A prospective cohort study was conducted among 74 adult patients with T1 DM and long-term disease duration (>15 years), in the period August - September 2024. The study is part of project No. 24034, funded by the Science Fund at the Medical University – Varna, Bulgaria. Statistical analysis was performed using IBM SPSS v.26, using the chi-square test ($\chi 2$) and Pearson (r) and Spearman (p) correlations.

Results: The $\chi 2$ test established a statistically significant relationship between balanced nutrition and PA in the prevention of the disease ($\chi^2 = 12.683$, df = 2, p = 0.002). Spearman correlation analysis demonstrated a statistically significant relationship between PA and BMI (Spearman's rho = 0.389, p = 0.01). Regular PA reduced glycated hemoglobin (HbA1c) by an average of 0.48% in athletes and led to a reduction in body mass ($\chi^2 = 7.60$, df = 1, p = 0.006).

Conclusion: Lifestyle changes, through interventions that promote healthy behavior, should be a priority part of diabetes care programs.

Key words: *type 1 diabetes mellitus, glycemic control, diet, physical activity, stress.*

INTRODUCTION

Type 1 diabetes mellitus (T1DM) is an autoimmune disease characterized by destruction of pancreatic β-cells and absolute insulin deficiency. Its management requires ongoing self-monitoring, insulin therapy, and an active role of the patient in the treatment process (1). Despite advances in technology and the availability of insulin pumps and continuous glucose monitoring systems, achieving optimal glycemic control remains a challenge for a large proportion of patients (2, 3).

Several studies have shown that lifestyle factors, including diet, physical activity (PA), and psychosocial stress management, have a significant impact on HbA1c levels and the risk of complications (4–6).

Diet is one of the strongest modifiable factors. Following a balanced diet with carbohydrate control and regular intake of foods with a low glycemic index is associated with better metabolic control and lower blood glucose (BG) variability (7). On the other hand, non-compliance with the diet plan leads to more frequent hyperglycemic episodes and an increased risk of hypoglycemia in the event of incorrect insulin dosing (8).

According to the International Society for Pediatric and Adolescent Diabetes (ISPAD, 2022), a personalized dietary regimen should be tailored to the patient's energy and nutritional needs, while also maintaining stable glycemic levels. It is recommended that carbohydrate intake be evenly distributed throughout the day and include the consumption of whole grains, fresh fruits and vegetables,

Address for correspondence:

Donika Kandilarova, PhD student
T +359 89545488
E-mail: d.kandilarova@gmail.com
Medical University of Varna, Varna 9002,
ul. Marin Drinov 55, Bulgaria
ORCID ID: https://orcid.org/0000-0002-4243-1840

foods with a low glycemic index, and unsaturated fats (9).

PA has a dual positive effect – it improves insulin sensitivity and supports mental well-being. Numerous studies have shown that regular, light to moderate PA reduces average HbA1c values between 0.3 and 0.6 %, regardless of the type of insulin therapy used (10). However, many patients avoid exercise due to fear of hypoglycemia or lack of knowledge about the correct adaptation of insulin doses (11). This highlights the need for educational programs that increase patients' confidence in self-management of the disease.

Another important but often underestimated factor is psychological stress. Chronic stress activates hormonal mechanisms that increase insulin resistance and glycemic profile (12). Patients who report high levels of stress in their daily lives show treatment failures and higher HbA1c values (13). Incorporating psychological support and stress management strategies into diabetes care programs has been shown to improve metabolic outcomes and quality of life (QOL) of patients (14, 15).

A multidisciplinary approach and team of specialists are needed in the treatment of T1D, combining the combined effect of diet, physical activity, and stress management on glycemic control and individualized support (16). Current studies show that combined interventions aimed at lifestyle changes can improve glycemic profile in patients with a long history of the disease (17, 18).

AIM

The present study aims to assess the influence of the main components of lifestyle (nutrition, physical activity and perceived stress level) on glycemic control in patients with T1DM.

MATERIAL AND METHODS

Study Design

A prospective cohort study was conducted among 74 adult patients with T1DM and long-term disease duration (> 15 years), in the period August – September 2024. The study is part of project No. 24034, funded by the Science Fund at the Medical University – Varna, Bulgaria. The study was approved by the Research Ethics Committee at the Medical University – Varna, with Protocol/ Decision No. 3/02.08.2024.

Criteria for inclusion and exclusion of participants

The study included 74 patients with T1DM aged over 18 and over 65 years, with disease duration >15 years, treated with insulin (multiple injections or insulin pump), with a desire to participate, certified by written informed consent (IC).

46 of them were excluded from the study, who declared a refusal to participate due to the presence of an acute or chronic disease, upcoming hospitalization, lack of time and desire to participate, lack of current telephone or email contact. The final number of participants included in the analysis is 72, since two lacked answers to 2/3 of the questions.

Data collection

An online questionnaire in electronic format, developed for the purposes of the study, was used to collect data. The questionnaire included structured, semi-structured and open-ended questions, combined into four sections, designed to assess key aspects of participants' awareness of diabetes, general knowledge of treatment and control of the disease, as well as socio-demographic data about the participants.

Statistical analysis

Data processing was performed using IBM SPSS Statistics v.26.0, with the application of the chi-square test ($\chi 2$) and Spearman (ρ) and Pearson (r) correlation. The level of statistical significance was accepted at $p < 0.05$.

RESULTS

Characteristics of the study population

The study included 72 patients with T1DM, of whom 37 (51.4%) were men and 35 (48.6%) were women, with a mean age of 48.2 ± 10.13 years (d=26÷73). The mean height of the participants included in the study was 172.5 (153-195; SD ± 13.7 cm), and their mean weight was 73.8 kg (50-121; SD ± 15.4 kg). The mean duration of the disease was 29.9 ± 9.64 years. The mean HbA1c value among the participants was 7 ± 2.45%, with 19 of them (33.3%) demonstrating poor glycemic control (HbA1c ≥ 7.0%) (Table 1).

Table 1. Clinical and demographic characteristics of participants.

Variables	N	Средно±SD
Age of participants (in years)	68	48.2±10.13
Duration of the disease (in years)	68	29.9±9.64
Height of participants (in cm)	73	172.5±13.74
Weight (kg)	72	73.8±15.47
BMI (kg/m²)	73	25.11±4.04
HbA1c (%)	57	7±2.45
Good glycemic control (HbA1c < 7%)	38	5.62±1.06
Bad glycemic control (HbA1c ≥7%)	19	9.75±2.09

BMI (body mass index) is an indicator that assesses body weight in relation to height. BMI is important in diabetes because it is directly related to both the development and control of the disease. It is a significant prognostic marker for glycemic control and body mass, an indicator of metabolic risk, and a guide to treatment selection. Higher BMI is usually associated with increased insulin resistance, worsening CG levels, the need for drug treatment, or an increased risk of chronic complications. BMI values among participants with type 1 diabetes mellitus are presented in Table 2.

Table 2. Body mass index (BMI) of participants

Gender	BMI (±SD)	n (%)
Male	25.83 (3.18)	36 (50.7)
Female	24.45 (4.76)	35 (49.2)

The results found a higher mean BMI > 1.38 units in men, who fall into the "overweight" category according to WHO criteria. In contrast, women are in the upper limit of "normal weight". The difference in the sample could also be due to the greater muscle mass in men, differences in lifestyle, dietary habits, physical activity or individual health status.

Pearson correlation analysis found a weak but statistically significant positive relationship between BMI and HbA1c ($r = 0.291$, $p = 0.024$), suggesting that with increasing body weight there is a trend towards higher HbA1c values. However, BMI only partially explains the variation in glycemic control, indicating the role of other factors, such as medication, nutrition and PA.

Influence of nutrition, physical activity and stress on glycemic control

The results found that for 76.1% (n=54) of the patients, adherence to a healthy diet is a key aspect in the treatment and control of the disease, in contrast to 22.5% (n=16) of them, for whom nutrition is not a significant factor. The participants preferred a low-carbohydrate (56.1%) diet and a low-lipid (29.8%), combined with a gluten-free (7%) or vegan (3.5%) diet, with an average number of meals per day of 3.4 ± 1.05.

The analysis of glycemic control in relation to dietary compliance shows that patients who strictly adhere to the diet (42%) achieve good control of HbA1c (<7%) compared to those who do not follow dietary recommendations (31%). At the same time, with poor HbA1c control (≥7%), the percentage of patients who adhere to the diet is lower (58%) compared to those who do not (69%). The overall statistical analysis using the χ^2 test showed a significant relationship between diet adherence and glycemic control ($\chi^2 = 52.250$, $df = 32$, $p = 0.013$), which supports the hypothesis that dietary regimen is an important factor in achieving optimal metabolic control in patients with T1DM (Table 3).

Table 3. Relationship between glycemic control in T1DM and behavioral factors in participants

Factor	Categories	Good control (HbA1c < 7%) n (%)	Bad control (HbA1c ≥7%) n (%)	Total n (%)	Chi-Square (χ^2, df, p)
Diet	Dieting	19 (42%)	26 (58%)	45 (77.6%)	$\chi^2 = 52.250$, df = 32, p = 0.013
	Not dieting	4 (31%)	9 (69%)	13 (22.4%)	
PA	Active	11 (34.4)	21 (65.6%)	32 (52.5%)	$\chi^2 = 39.281$, df = 34, p=0.245
	Inactive	8 (27.6)	21 (72.4%)	29 (47.5%)	
Stress	Low	3 (50%)	3 (50%)	6 (9.8%)	$\chi^2 = 125.752$, df = 102, p=0.55
	Moderate	14 (40%)	21 (60%)	35 (57.4)	
	High	1 (5.9%)	16 (94.1%)	17 (27.9%)	
	Unspecified	1 (33.3%)	2 (66.6%)	3 (4.91%)	

Together with nutritional behavior, PA is an essential element of the overall complex therapy of patients. It improves glycemic control, reduces the risk of complications and improves the general health and psycho-emotional state of patients. With proper planning and control, exercises are completely safe and extremely beneficial for every patient with this disease.

For overweight and obese diabetics, PA is part of the treatment plan and, together with the diet, helps to reduce body weight and maintain it within healthy limits.

Spearman's correlation analysis revealed a statistically significant relationship between physical activity and BMI (Spearman's rho = 0.389, p = 0.01). Regular exercise reduces HbA1c by an average of 0.48% in athletes and leads to a reduction in body mass ($\chi^2 = 7.60$, df = 1, p = 0.006).

Over 50% of the participants 52.7% (n=39) indicated that PA was part of their daily routine in the form of walking 34 (85%) to the store, walking in the park, housework, gardening or attending as a hobby related to cycling 13 (32.5%), swimming 9 (22.5%), aerobics/dancing 7 (17.5%) and weightlifting 4 (10%). The results also showed the average time spent on training: 65.37 minutes (SD±5.6), with an average frequency of training sessions per week 4.31 times (SD±2.4).

The impact of PA on glycemic control showed that patients who were regularly physically active had a slightly higher proportion of good HbA1c control (<7%) compared to inactive patients (34.4% vs. 27.6%). The percentage of patients with poor control (HbA1c ≥7%) was similar between the two groups – 65.6% in the active and 72.4% in the inactive. Despite these trends, statistical analysis using the χ^2 test did not show a significant association between physical activity and HbA1c levels ($\chi^2 = 39.281$, df = 34, p = 0.245), suggesting that in this cohort physical activity itself is not a major factor in achieving optimal metabolic control (Table 3).

We investigated the presence of a statistical relationship between the variables FA and diet in the management of T1DM. The results obtained demonstrate the beneficial influence of the studied indicators in the prevention of the disease ($\chi^2 = 12.683$, df = 2, p = 0.002).

Maintaining good mental health is as important for glycemic control as diet and exercise, so that patients can live a full and balanced life. The results of the study reported that for 41 (55.4%) of the participants, stress was in the moderate or average range. This means that for these patients, the stress associated with managing the disease is still without serious negative consequences. For 21 (28.4%) of them, stress was in the high range, which is a significant proportion. These patients are likely to experience difficulties in coping with anxiety and even exhaustion, which can negatively affect glycemic control.

In 9 (12.2%) of the participants, stress was at low levels, which means that these patients are probably better adapted to their condition and effectively apply strategies to cope with the burden of diabetes in their daily lives. For those of them who cannot determine its level, it may mean that they are either not aware of their own emotional state or do not recognize its symptoms.

We analyzed the degree of association between the level of stress and the type of PA as a means of coping with it. The results proved borderline values of statistical dependence between swimming as a possible means of coping with it in daily life (χ^2 = 7.776, df = 3, p = 0.051).

The distribution of stress levels among the participants shows a clear trend: with low stress, good control of HbA1c (<7%) in 50% of the patients, and with moderate stress – in 40% of the patients. In the high-stress group, the proportion of patients with good control dropped sharply to 5.9%, with 94.1% of them having HbA1c ≥7%. In those with an undetermined level of stress, 33.3% achieved HbA1c <7%. Despite the emerging unfavorable glycemic picture in the high-stress patients, the χ^2 test did not find a statistically significant relationship between the level of stress and glycemic control (χ^2 = 125.752, df = 102, p = 0.55). This indicates that although high stress coincides with more frequent poor control, the weight of evidence in this sample is not sufficient to statistically confirm an association (Table 3).

Analysis of behavioral factors showed different strengths of association with metabolic control. Dietary adherence demonstrated a significant association with HbA1c levels, with 42% of patients adhering to a diet achieving HbA1c <7%, compared to 31% among those not adhering to dietary recommendations (χ^2 = 52.250, df = 32, p = 0.013). More moderate differences were observed in physical activity: 34.4% of active patients achieved good glycemic control, compared to 27.6% of inactive patients. Despite these variations, a statistically significant association was not found (χ^2 = 39.281, df = 34, p = 0.245). Regarding stress, the lowest proportion of good control was observed in patients with high stress (5.9%), while in moderate and low stress this proportion reached 40% and 50%, respectively. Despite the clear trend towards poorer control under high stress, the χ^2 test did not show a statistically significant relationship (χ^2 = 125.752, df = 102, p = 0.55). These results highlight that among the factors studied, diet stands out as the only behavioral element that shows a statistically verifiable relationship with metabolic control in patients with T1DM.

DISCUSSION

The results obtained show that dietary adherence and PA levels are associated with lower HbA1c values, while higher perceived stress correlates with poorer metabolic control. These observations are consistent with previous international studies that have demonstrated that adherence to a balanced diet and regular physical activity have a significant impact on the glycemic profile in T1DM (19–21). Ndahura et al. (22) indicated that patients who adhere to structured eating plans with carbohydrate control achieve lower glucose variability and better overall metabolic stability. Similar results have been reported in studies by Wilson et al. (23), according to which high dietary adherence is associated with a reduction in HbA1c by about 0.5–0.7%.

The role of PA as a modifiable factor is also well documented. Metcalf et al. (24) found that moderate to vigorous activity of at least 150 min per week resulted in statistically significant reductions in HbA1c, regardless of age and gender.

From a psychological perspective, stress is a significant barrier to diabetes management. Increased perceived stress can activate the hypothalamic-pituitary-adrenal axis, leading to increased secretion of cortisol and counterregulatory hormones that impair insulin sensitivity (25, 26). Our data show that patients with higher levels of stress have worse glycemic control, which is consistent with the observations of Ahola et al. (27). These results support the need to integrate psychological support and stress management interventions into routine diabetes care.

This is consistent with the findings of Hilliard et al. (28), who indicated that combined interventions aimed at improving dietary habits and stress management lead to long-term improvements in glycemic control.

CONCLUSION

The results of this study highlight the key importance of lifestyle in the management of type 1 diabetes mellitus. Better adherence to a healthy diet, regular physical activity and effective stress management are associated with lower HbA1c values and better metabolic control.

Interventions aimed at behavior change and patient education should be integrated as a permanent element of diabetes care. The development of multidisciplinary programs involving endocrinologists, dieticians and psychologists could improve clinical outcomes and quality of life of patients with T1DM in Bulgaria.

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