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THE IMPACT OF VARIOUS LIFESTYLE FACTORS ON BLOOD GLUCOSE CONTROL IN INDIVIDUALS WITH TYPE 2 DIABETES: A REVIEW OF CURRENT RESEARCH AND CLINICAL RECOMMENDATIONS

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ABSTRACT

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by hyperglycemia resulting from peripheral insulin resistance and progressive β-cell dysfunction. The disease leads to micro- and macrovascular complications, significantly impairing patients' quality and length of life. Lifestyle factors, such as diet, physical activity, body weight, sleep, stress, and substance use, play a key role in the pathogenesis of T2DM. Numerous studies show that modifying these factors improves glycemic control, lowers HbA1c, reduces the need for hypoglycemic medications, and in some cases may induce disease remission. Low-carbohydrate, Mediterranean, and low-calorie diets improve metabolic parameters and support weight reduction. Regular physical activity, including aerobic, resistance, and high-intensity interval training, increases glucose uptake by muscles, improves insulin sensitivity, and reduces visceral fat. Optimal body weight, waist circumference, and sleep duration and regularity significantly affect blood glucose levels and HbA1c control. A comprehensive approach addressing diet, physical activity, weight management, and sleep improvement promotes effective glycemic control and reduces the risk of T2DM complications.

KEYWORDS

Type 2 Diabetes, Glycemic Control, Diet, Physical Activity, Body Weight, Sleep, HbA1c

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1. Introduction

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder and one of the most significant health challenges of the modern world, being a leading cause of morbidity and mortality globally (1). It is characterized by hyperglycemia due to a combination of peripheral insulin resistance and progressive β-cell dysfunction (2,3). According to the World Health Organization (WHO), the number of people with diabetes has risen from approximately 200 million in 1990 to over 830 million in 2022, with projections indicating further substantial growth, making T2DM a global epidemic (4). The disease leads to numerous microvascular complications (retinopathy, nephropathy, neuropathy) and macrovascular complications (coronary artery disease, stroke, peripheral atherosclerosis), which significantly reduce patients' quality and length of life (5–7).

Environmental factors, particularly lifestyle-related ones, play a crucial role in T2DM pathogenesis. Diets high in simple sugars and saturated fats, sedentary behavior, chronic stress, sleep deprivation, and smoking significantly contribute to insulin resistance and metabolic disorders (8,9). Conversely, lifestyle modification has been shown to improve glycemic control, reduce HbA1c, decrease the need for hypoglycemic drugs, and in some cases lead to disease remission (10–13).

Current guidelines from the American Diabetes Association (ADA) and the European Association for the Study of Diabetes (EASD) recommend lifestyle interventions as the foundation of therapy for all patients with T2DM. These include a balanced diet, regular physical activity, weight reduction in cases of overweight or obesity, sleep improvement, avoidance of harmful substances, and stress reduction techniques (14).

Lifestyle medicine emphasizes healthy living as an integral component of chronic disease prevention and management (15–17). This review aims to present the current evidence regarding the impact of lifestyle factors on blood glucose levels in individuals with T2DM.

2. Research materials and methods

This review included randomized trials, meta-analyses, systematic reviews, and prospective studies assessing the impact of lifestyle factors on glycemic control in T2DM. Data were identified via PubMed, Scopus, and Web of Science using keywords such as "type 2 diabetes," "glycemic control," "diet," "physical activity," "weight loss," "sleep," and "lifestyle interventions." Inclusion criteria comprised English or Polish publications from 2010–2025 focusing on adult T2DM patients. Studies on type 1 diabetes, preclinical studies, and single-case reports were excluded. Metabolic parameters (HbA1c, fasting glucose) and clinical outcomes (weight reduction, insulin sensitivity, cardiovascular risk) were analyzed.

3.1. Diet

Diet is a key factor in glycemic control for T2DM, with evidence from randomized trials and reviews demonstrating both mechanistic and clinical effects (18). The type of carbohydrate consumed is fundamental. Studies comparing low-carbohydrate diets with conventional diets show faster and often greater reductions in postprandial glucose and HbA1c in the short term, linked to reduced dietary glucose intake. Long-term maintenance depends on adherence and medication management (18–20). In a study by Kirsten S. Dorans, participants on a low-carbohydrate diet experienced after six months a mean HbA1c reduction of 0.23%, fasting glucose decrease by 10 mg/dl, and average weight loss of nearly 6 kg (18). Similar results were reported in a Japanese study by Yamada et al., where limiting carbohydrate intake to ~130 g/day improved metabolic parameters in patients with poorly controlled T2DM, with an average HbA1c reduction of 0.65% after 6 months compared to the control group (20). Additionally, Grant D. Brinkworth and Pennie J. Taylor confirmed that an individualized low-carbohydrate nutrition program can not only reduce HbA1c but also allow a reduction in hypoglycemic medication doses (21). The authors note that the effectiveness of such interventions depends on close clinical monitoring and educational support, which increase the likelihood of maintaining long-term changes

Other dietary patterns, such as the Mediterranean diet, show evidence of improved glycemic control and favorable effects on cardiovascular risk factors. Reviews and RCTs suggest that individuals following a Mediterranean diet achieve moderate HbA1c reductions compared to standard care, with effect sizes typically ranging from 0.1 to 0.6% depending on the diet and observation period. These findings support choosing a diet rich in vegetables, fruits, olive oil, and fish as a metabolically beneficial strategy for T2DM patients (22).

Comparative studies indicate that various interventions achieve their greatest effects when combined with weight reduction. A notable example is the DiRECT study, where intensive low-calorie dietary interventions in primary care settings led to remission in a significant proportion of participants, with 46% achieving remission after one year. Long-term analyses show a correlation between the magnitude of weight loss and sustained remission probability (23). Similar outcomes were observed in the DIADEM-I study, which also demonstrated that intensive dietary intervention improves metabolic parameters in patients with poorly controlled T2DM (24).

In prevention, the Diabetes Prevention Program (DPP) showed that intensive lifestyle interventions focusing on weight loss and increased physical activity reduced diabetes incidence by ~58% in individuals with impaired glucose tolerance compared to controls, highlighting that dietary and health behaviors affect both disease management and prevention (25).

Clinical trials and observational studies also provide evidence regarding processed foods and sugary beverages; high intake is associated with worse glycemic control, increased insulin resistance, and obesity, hindering desired HbA1c targets. Clinical recommendations therefore advise against regular consumption of added sugars and highly processed products (26,27).

Comparisons indicate that dietary intervention effectiveness depends on the studied population and intervention duration. Short-term low-carb diets often yield rapid and substantial reductions in glucose and HbA1c, while long-term effects may be smaller or dependent on adherence. For instance, a systematic review by Ichikawa et al. showed that long-term low-carb diets did not lead to significant HbA1c differences compared to control diets (28). In contrast, Mediterranean diets, though slower in effect, are easier to maintain and provide sustained metabolic and cardiometabolic benefits. A systematic review by Whiteley and Benton indicated that Mediterranean, low-glycemic, plant-based, and low-carb diets effectively reduce HbA1c in T2DM patients (29). Similarly, a meta-analysis by Yuan et al. showed that the Mediterranean diet was the most effective in improving glycemic control, achieving the highest SUCRA score (88.15%) compared to other diets (30). The choice of an optimal dietary pattern should be individualized, taking into account patient preferences, therapeutic goals, and the feasibility of maintaining changes in the long term

Optimal dietary choice should be individualized, considering patient preferences, therapeutic goals, and long-term adherence. Practical recommendations include reducing simple sugars and processed foods, increasing dietary fiber, favoring unsaturated fats, and considering weight-loss promoting diets (low-calorie or controlled carbohydrate reduction) under medical supervision. Evidence from DiRECT and prevention programs like DPP shows that greatest and most durable glycemic benefits occur when dietary changes are part of a broader program including weight loss, physical activity, and behavioral support (31–33).

3.2. Physical activity

Physical activity is one of the key pillars of non-pharmacological treatment of type 2 diabetes. Its importance stems from its multidimensional impact on glucose metabolism, lipid metabolism, and body weight. The mechanisms underlying this phenomenon include both the immediate effects of a single exercise session and long-term metabolic adaptations. During exercise, glucose uptake by muscles increases independently of insulin action, thanks to the increased translocation of GLUT4 transporters to the cell membrane, which allows blood glucose levels to be lowered even in people with insulin resistance (34–36). Regular activity, on the other hand, increases the number and sensitivity of GLUT4 transporters and improves mitochondrial function in muscles, which translates into a long-term increase in insulin sensitivity (37–39).

One of the best-documented effects of physical activity in people with type 2 diabetes is an improvement in glycemic indicators, including a reduction in HbA1c levels and the HOMA-IR insulin resistance index. A study by Umpierre et al. involving over 2,000 patients showed that aerobic exercise programs, resistance training, or combined exercise programs lead to an average decrease in HbA1c of 0.67 percentage points compared to no activity, with these effects being greater in programs lasting at least 12 weeks and involving a minimum of 150 minutes of activity per week, which is consistent with the recommendations of the American Diabetes Association (ADA) (34,40). Similar results were obtained in a more recent meta-analysis by Garcia et al. from 2025, covering 158 studies with 17,059 participants, which showed that all forms of exercise – high-intensity interval training (HIIT), aerobic training, resistance training, and combinations thereof – lead to a reduction in HbA1c compared to the control group, with the largest decrease in HbA1c observed in the HIIT group (-0.61%), followed by the combined training (-0.58%) and aerobic training (-0.58%) groups, while resistance training also brought benefits, albeit to a lesser extent (-0.40%), and workouts lasting longer than 150 minutes per week were more effective in reducing HbA1c than shorter ones (41). It is also worth noting that not only structured exercise programs, but also advice on physical activity can be beneficial, as in a study by Umpierre et al. in 2011, interventions involving physical activity advice, especially when combined with dietary advice, led to an average reduction in HbA1c levels of 0.58%, suggesting that even less intensive forms of support can have a positive effect on glycemic control in people with type 2 diabetes (34).

According to the ADA guidelines for 2022, adults with type 2 diabetes should engage in moderate or vigorous aerobic activity for at least 150 minutes per week, spread over a minimum of three days, with no more than two days between sessions (40). It is also recommended to perform resistance training at least twice a week and, if possible, to supplement the program with stretching and balancing exercises. Regular activity of this type not only leads to improved glycemia, but also to lower blood pressure and triglyceride levels, which further reduces cardiovascular risk (34).

When comparing different types of exercise, studies show that each has a beneficial effect on glycemic control, although the mechanisms of action are different. Aerobic exercise (e.g., brisk walking, cycling, swimming) increases the use of glucose as an energy source and improves insulin sensitivity by increasing the activity of oxidative enzymes in the muscles (42–44). Resistance (strength) training, on the other hand, increases muscle mass, which raises the basal metabolic rate and the ability to store glucose in skeletal muscles. In a systematic review and meta-analysis by Fan, Lin, and Kim (2023) showed that in patients with type 2 diabetes, 12 weeks of resistance training resulted in an average decrease in HbA1c of 1.09%, a reduction in body weight of 4.25 kg, a decrease in triglyceride and LDL cholesterol levels, and an improvement in the HOMA-IR index (45). Scientific research shows that various forms of physical activity have a beneficial effect on glycemic control in patients with type 2 diabetes, although the mechanisms of their action are different. Aerobic training, such as brisk walking, cycling, or swimming, increases the use of glucose as an energy source and improves insulin sensitivity by increasing the activity of oxidative enzymes in muscles (46). Resistance (strength) training, on the other hand, increases muscle mass, which raises the basal metabolic rate and the ability to store glucose in skeletal muscles (47). In a meta-analysis by Umpierre, Ribeiro, Kramer et al. (2011), which included 47 randomized controlled trials (8,538 patients), it was found that aerobic training reduced HbA1c by an average of 0.73%, resistance training by 0.57%, and combined training (aerobic + resistance) by

0.51% compared to control groups. Although the greatest decrease in HbA1c was observed with aerobic training alone, combined training offers comprehensive clinical benefits, combining moderate improvement in glycemia with the possibility of increasing muscle mass and strength and improving other metabolic parameters (34).

More and more studies are focusing on high-intensity interval training (HIIT), which can deliver similar or greater benefits than traditional moderate-intensity programs in a short period of time. A study by Angela S Lee and co-authors showed that a 12-week HIIT program improved both HbA1c and HOMA-IR to a degree comparable to classic aerobic training, despite a lower total exercise volume (48). Similarly, Madsen's study showed that an 8-week HIIT program in patients with type 2 diabetes led to significant reductions in fasting glucose, HbA1c, and improvements in HOMA-IR, with less total training volume compared to traditional aerobic training (49).

The molecular mechanisms behind the improvement in insulin resistance include increased expression of genes responsible for fatty acid oxidation, decreased concentrations of inflammatory markers such as IL-6 and TNF-α, and increased activity of AMPK kinase in muscles, which regulates glucose and lipid metabolism (42). In addition, regular activity causes a decrease in visceral adipose tissue, which is a source of pro-inflammatory cytokines, leading to further improvement in insulin sensitivity (50).

The importance of an appropriate "dose" of physical activity for metabolic effects is emphasized by numerous meta-analyses. Zhang's study showed that HbA1c reduction correlates linearly with total exercise time; people who exercised for more than 250 minutes per week achieved an average HbA1c reduction of 0.8%, while those who exercised for less than 150 minutes per week achieved a reduction of 0.3% (51). These results indicate that gradually increasing training volume may bring additional clinical benefits.

In summary, regular physical activity is one of the most effective ways to improve glycemic control and insulin sensitivity in patients with type 2 diabetes. The best results are observed when combining aerobic and resistance exercises performed at the frequency recommended by the ADA, with interval training being a valuable alternative for people with limited time. The effects include a significant reduction in HbA1c (by an average of 0.6–0.8 p.p.), improvement in HOMA-IR, and beneficial changes in body composition and lipid profile, which translates into a lower risk of vascular complications (34,40,42).

3.3. Body weight and obesity reduction

Obesity, especially in the form of excess abdominal fat, is one of the main risk factors for the development of type 2 diabetes mellitus (T2DM) and its complications, as visceral adipose tissue is a metabolically active organ that secretes pro-inflammatory cytokines, which increase insulin resistance and disrupt glucose homeostasis. Body mass index (BMI) and waist circumference (WC) are commonly used tools for assessing metabolic risk, but studies have shown that waist circumference and its changes are a more sensitive indicator of diabetes risk than BMI alone, as they reflect the accumulation of fat in the abdominal area, which is associated with a higher risk of insulin resistance and metabolic syndrome (52–54). Weight reduction, even by 5–10%, leads to a significant improvement in glycemic control in people with T2DM, lowers blood glucose levels, increases tissue sensitivity to insulin, and reduces the need for hypoglycemic drugs, as demonstrated in numerous randomized clinical trials and meta-analyses (55). These benefits are noticeable in both the short and long term, and maintaining weight loss contributes to reducing the risk of cardiovascular complications, improving the lipid profile and quality of life of patients, as emphasized by studies such as Look AHEAD and DiRECT (23,56).

Interventions aimed at weight reduction include lifestyle changes, such as calorie restriction, increased physical activity, and dietary modification, as well as bariatric surgery in selected cases. Surgeries such as Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) not only lead to significant weight loss, but in many cases also induce remission of type 2 diabetes mellitus (T2DM). Studies have shown that 10 years after RYGB surgery, as many as 31% of patients achieved complete remission and 15% achieved partial remission, with the lowest HbA1c level before surgery being a prognostic factor for long-term remission (57). The mechanisms responsible for improving glycemia after bariatric surgery include changes in intestinal hormones such as GLP-1 and PYY, reduction of insulin resistance in the liver and muscles, reduction of visceral fat, and changes in the intestinal microbiome (58). It is worth noting that bariatric surgery is particularly effective in patients with high BMI and long-standing T2DM, in whom pharmacotherapy and lifestyle changes have not been sufficiently effective, as documented in systematic reviews and meta-analyses (59).

In addition, reducing waist circumference, rather than just total body weight, is a key factor in improving insulin sensitivity and reducing blood glucose levels, as visceral adipose tissue is responsible for the production of pro-inflammatory adipokines such as TNF-α, IL-6, and resistin, which exacerbate insulin resistance (60). A reduction in waist circumference, achieved through calorie restriction, increased physical activity, or surgical interventions, leads to improved glucose metabolism, reduced fasting insulin and HbA1c levels, and beneficial changes in the lipid profile (61). In the context of T2DM treatment, glycemic monitoring, regular check-ups, and individualized adjustment of pharmacological therapy are essential to maintain stable blood glucose levels, avoid hypoglycemia, and ensure the effectiveness of weight reduction interventions (62).

3.4. The Role of Sleep in Diabetes

Sleep plays a key role in maintaining metabolic health, and sleep disorders have a significant impact on the risk of developing type 2 diabetes and glycemic control in people with the disease. Studies show a correlation between sleep duration and the risk of type 2 diabetes. The lowest risk is found in people who sleep 7-8 hours a day, while sleeping less than 6 hours or more than 9 hours increases the risk by 9% and 14%, respectively, compared to people with optimal sleep duration (63). Even people who eat a healthy diet are at higher risk of type 2 diabetes if they regularly sleep less than 6 hours a day (64).

In people with type 2 diabetes, both short and excessive sleep duration and poor sleep quality are associated with poorer glycemic control. People who sleep more than 8 hours a day are 2.6 times more likely to have poor glycemic control compared to those who sleep 7–8 hours a day (65). In addition, poorer sleep quality, as assessed by a Pittsburgh Sleep Quality Index (PSQI) score >5, correlates with higher fasting glucose, postprandial glucose, and HbA1c levels (66).

Not only the length and quality of sleep matter, but also its regularity. Irregular sleep patterns, such as changes in bedtime and wake-up times, can negatively affect glycemic control in people with type 2 diabetes. Studies show that greater variability in bedtime and sleep duration is associated with poorer metabolic outcomes, including higher HbA1c levels and greater blood glucose variability (67). In clinical practice, it is recommended that people with type 2 diabetes aim to maintain regular sleep hours, which can help stabilize glucose levels. Interventions aimed at improving sleep regularity, such as light therapy or changing bedtime habits, may be beneficial for glycemic control (68). Incorporating these practices into your daily routine, along with a healthy diet and physical activity, can be an important part of comprehensive type 2 diabetes management.

6. Discussion

An analysis of available studies shows that lifestyle plays an important role in glycemic control in patients with type 2 diabetes. Low-carbohydrate, Mediterranean, and low-calorie diets improve HbA1c levels and, when combined with weight loss, can lead to remission of the disease (18). Regular physical activity, including aerobic, resistance, and high-intensity interval training, increases glucose uptake by muscles, improves insulin sensitivity, and reduces visceral fat (39,41,46,69). Weight loss and waist circumference reduction are particularly effective in lowering blood glucose levels and reducing insulin resistance (70). Sleep disorders, including sleep deprivation, excess sleep, and irregular sleep patterns, are associated with poorer glycemic control, indicating the need to monitor and optimize sleep patterns in patients with T2DM (65,67,68). The results of the study emphasize that lifestyle interventions are most beneficial when they are comprehensive and individualized, covering diet, physical activity, weight control, and behavioral support (28,71). The lifestyle medicine approach allows for effective disease management, reduced medication requirements, and a lower risk of complications.

7. Conclusions

Lifestyle modification is a key component of type 2 diabetes treatment. An appropriate diet, regular physical activity, weight control, and improved sleep quality and regularity lead to significant improvements in glycemic control and a reduced risk of complications. The effectiveness of interventions depends on individualized recommendations and educational support for patients. A comprehensive lifestyle medicine approach should be an integral part of T2DM treatment, and its implementation can contribute to improved clinical outcomes, quality of life, and long-term remission of the disease.

Disclosure
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