THE IMPACT OF A LOW-CARBOHYDRATE DIET ON METABOLIC PARAMETERS IN PATIENTS WITH TYPE 1 AND TYPE 2 DIABETES MELLITUS

Wpływ diety niskowęglowodanowej na parametry metaboliczne pacjentów z cukrzycą typu 1 i typu 2

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Abstract

The global prevalence of diabetes mellitus reached 382 million in 2013 and is expected to rise to 592 million by 2035. The consequences of diabetes mellitus, especially if it is poorly controlled, might be dramatic and lead to life-threatening conditions. Therefore, it is crucial to prevent diabetes mellitus, diagnose it as early as possible, and treat it effectively. In addition to medications, lifestyle modification – especially diet and eating habits – seems to be the instrumental factor in the management of diabetes mellitus. This review is focused on the benefits and risks of a low-carbohydrate diet in patients with type 1 and 2 diabetes mellitus. Clinical trials containing data on changes in metabolic parameters, such as fasting glucose, fasting insulin, and HbA_{1c}, resulting from the use of a low-carbohydrate diet by patients with diabetes mellitus were analyzed. Most of the included studies showed improvements in these parameters. Only one study reported an increase in HbA_{1c}, likely due to patients' non-compliance with dietary instructions. Consequently, devoting time to clear explanations of dietary rules, providing help in implementing them, and further monitoring of patients' food intake seem to be crucial. Although the outcomes of this study showed a beneficial effect of a low-carbohydrate diet on metabolic parameters, conducting further studies is still required to clearly and explicitly define all positive and promising outcomes of this review, as well as risks associated with the use of a low-carbohydrate diet by patients with diabetes mellitus.

Streszczenie

W 2013 r. liczba chorych na cukrzycę na świecie wynosiła 382 miliony, a szacuje się, że do 2035 r. wzrośnie do 592 milionów. Konsekwencje tej choroby, szczególnie jeśli nie jest odpowiednio kontrolowana, mogą być dramatyczne i prowadzić do stanów zagrożenia życia. Z tego powodu niezwykle ważne jest zapobieganie cukrzycy, dążenie do szybkiego jej rozpoznania oraz skutecznego leczenia. W walce z tą chorobą oprócz farmakoterapii niewątpliwie kluczowy jest zdrowy styl życia, w szczególności zmiana diety i modyfikacja nawyków żywieniowych. W tym przeglądzie skupiono się na korzyściach i zagrożeniach wynikających ze stosowania diety niskowęglowodanowej u pacjentów z cukrzycą typu 1 i typu 2. Przeanalizowano badania kliniczne zawierające dane na temat zmian w parametrach metabolicznych, takich jak glukoza na czczo, insulina na czczo i HbA_{1c}, które wystąpiły w wyniku stosowania tej diety przez pacjentów z cukrzycą. W większości uwzględnionych badań zaobserwowano poprawę tych parametrów. Tylko w jednym badaniu odnotowano wzrost HbA_{1c} u chorych na cukrzycę typu 1, niemniej był on prawdopodobnie rezultatem nieprzestrzegania zasad diety przez pacjentów. W związku z tym konieczne wydaje się poświęcenie czasu na objaśnienie pacjentom założeń diety niskowęglowodanowej, pomoc w jej wdrożeniu oraz późniejsze monitorowanie spożywanych przez nich pokarmów. Pomimo że wyniki prezentowanego przeglądu wskazują na korzystny wpływ diety niskowęglowodanowej na parametry metaboliczne chorych na cukrzycę, konieczne jest przeprowadzenie dalszych badań w celu jasnego i jednoznacznego określenia wszystkich korzyści i zagrożeń wynikających ze stosowania diety niskowęglowodanowej przez pacjentów z cukrzycą.

Introduction

The global prevalence of diabetes mellitus (DM) reached 382 million in 2013. By 2035, it is expected to rise to 592 million [1]. This increase is likely driven by factors such as unhealthy and unbalanced diets, lack of physical activity, and the general global rise in obesity rates. The prevalence of type 2 diabetes mellitus (T2DM) increases with age, and because Western societies are consistently aging, the number of new diabetes cases continues to grow steadily. Moreover, longer life expectancy leads to an increase in the prevalence of DM. Similarly, according to some studies, this may apply not only to T2DM but also to T1DM (type 1 diabetes mellitus) [2]. The consequences of DM, especially if it is poorly controlled, might be very severe and lead to life-threatening conditions such as neuropathy, retinopathy, cardiovascular diseases, heart attack, and stroke. Taking these facts into consideration, it is crucial to prevent and effectively treat DM as early as possible [3]. In addition to pharmacological treatment, there are many other recommendations for diabetics. Chief among these are maintaining a proper body weight and balanced glucose levels, which are instrumental in DM management. Secondly, physical activity should be on the daily schedule of every patient with DM. Even low-intensity activities, such as walking, may be immensely beneficial. Smoking cessation is strongly recommended for all individuals, especially those with chronic diseases. When it comes to diet, there are special rules which should be implemented by all diabetics. Firstly, patients are advised to consume low-glycemic, well-balanced meals. It would be additionally beneficial to consume 4–5 meals per day at regular intervals (every 3–4 hours). Monosaccharides should be avoided as much as possible, which may be challenging due to their high prevalence in all kinds of food products such as milk, flour, yoghurts, ketchup, and many others. In cases of excess body weight, a caloric deficit should be introduced. The specific amount of calories will depend among others on the individual's primary body weight and the level of daily activity. Patients are also recommended to exclude products rich in monosaccharides, those with a high content of saturated fats, and ultra-processed foods. In contrast, diabetics should consume more complex carbohydrates and products rich in fiber, which can be found predominantly in products of plant origin. Maintaining a healthy body weight is instrumental in DM management [4]. It is proven that diet is responsible for 80% of weight loss success, whereas physical activity contributes around 20%. Currently, various types of diets and eating habits are gaining popularity, also among individuals who do not suffer from being overweight or any gastrointestinal disruption. Increasingly, they decide to implement restricted diets and exclude whole groups of products without any medical indication. Intermittent fasting, ketogenic diets, low-carbohydrate diets, gluten-free diets, or plant-based diets are the most common choices as some people consider them as the perfect cure for all health conditions [5]. All the above mentioned diets may affect the body in various ways, both positively and negatively. This review focuses on the low-carbohydrate diet, where daily carbohydrate intake should not exceed 30 g or 26% of total caloric intake.
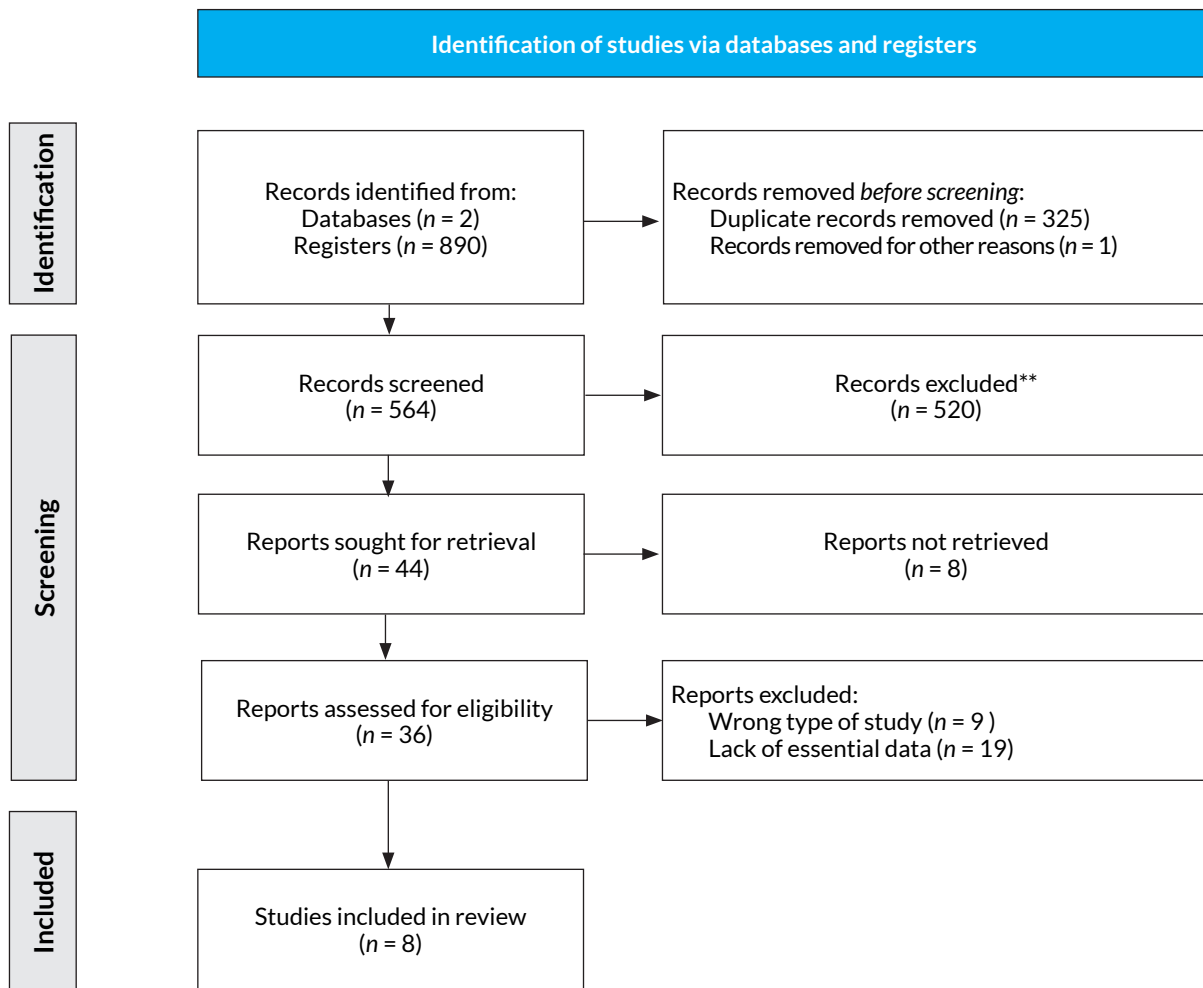
Aim of the review

This review was conducted to estimate whether a low-carbohydrate diet may be beneficial for diabetic patients.

Material and methods

Databases such as Pubmed and Scopus were screened systematically to identify articles published in 2020–2023 that contained information about the influence of a low-carbohydrate diet on metabolic parameters in patients with diabetes mellitus (both type 1 and type 2). This review was conducted according to the PRISMA protocol (Fig. 1) and the PICO method. The search process is shown in the chart below. Titles and abstracts were screened independently by the authors. Only randomized clinical trials published in 2020–2023 were included in the review. An additional inclusion criterion was that the articles had to report on the metabolic parameters in accordance with a low-carbohydrate diet in patients with diabetes mellitus type 1 or type 2. The required parameters included fasting insulin level OR/AND glucose level OR/AND HbA_{1c}. Altogether, 890 articles were found. After the removal of duplicates, 564 articles remained. All titles and abstracts were screened independently. Forty-four were included for further analysis and afterwards read in full. Ultimately, eight studies were included in the review.

Results

Most of the included studies indicate that a low-carbohydrate diet may be beneficial in T2DM patients. Specific changes in fasting glucose levels, HbA_{1c} levels, and fasting insulin level are presented in Table 1, Table 2, and Table 3, respectively. One of the studies enrolled 11 individuals with T2DM and divided them into three groups (low-carbohydrate diet, low-carbohydrate diet + 15-minute walk post-meal, and low-glycemic diet). Those assigned to a low-carbohydrate diet limited their carbohydrate intake to 10% of total energy for four days. The experiment was repeated three times with 9–14 days washout periods between interventions. There was a significant decrease in fasting glucose and the proinsulin-C-peptide ratio in the groups implementing a low-carbohydrate diet. These changes did not occur in individuals on low-glycemic index diet. Thus, it indicates the superiority of a low-carbohydrate diet over a low-glycemic diet in patients with T2DM [6]. Similar outcomes were observed in another study, during which diabetics with poorly controlled T2DM (HbA_{1c} ≥7.5%) had reduced their carbohydrate intake to 90 g/day for 18 months. Outcomes revealed that the HbA_{1c} and two-hour postprandial serum glucose values were significantly lower in the low-carbohydrate diet group than in the traditional diabetic diet [7]. A trial conducted in China, which lasted for three months, indicates that the low-carbohydrate diet is more effective in lowering HbA_{1c} than the low-fat diet [8]. Nevertheless, the low-fat diet seems to be more efficient in lowering triglycerides and cholesterol levels [9]. A low-carbohydrate diet may not only significantly improve the level of metabolic parameters related to DM, but it also help regain healthy body mass

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Figure 1. PRISMA flow diagram

in T2DM patients, who do not receive any pharmacological treatment [10]. It is commonly believed that exercises are a crucial factor in weight loss. However, one of the conducted studies shows that a low-carbohydrate diet might be even more effective in obese patients than physical activity – individuals lose 3.56 kg through diet compared to 1.24 through exercise [11]. Reducing carbohydrates while increasing fat and protein intake may seem dangerous – especially in patients with kidney diseases. Nonetheless, the out-

Table 1. Overview of clinical studies on the effects of a low-carbohydrate diet on fasting glucose levels in patients with type 2 diabetes

Authors/ Year published/ Time of study	Number of patients and median age	Duration of diet	Type of diabetes	Fasting glucose pre	Fasting glucose post
Zainordin et al./ 2021/ 2019–2020/ [12]	14 Age: 57	12 weeks	2	8.2 mmol/L = 147.6 mg/dL	6.3 mmol/L = 113.4 mg/dL
Dorans et al./ 2022/ 2018–2021/ [10]	75 Age: 59.3	6 months	2	6 mmol/L = 108.3 mg/dL	5.55 mmol/L = 99.9 mg/dL
Chen et al./ 2022/ 2018–2019/ [7]	36 Age: 63.3	18 months	2	8.9 mmol/L = 160.6 mg/dL	7.4 mmol/L = 133.6 mg/dL
Wang et al./ 2018/ 2015–2016/ [8]	24 Age: 66.79	3 months	2	8.28 mmol/L = 149.04 mg/dL	6.67 mmol/L = 120.06 mg/dL
Han et al./ 2021/ 2019–2020/ [9]	60 Age: 51.45	6 months	2	8.1 mmol/L = 145.8 mg/dL	6.2 mmol/L = 111.6 mg/dL
Cai et al./ 2021/ 2018–2019/ [11]	22 Age: 25.36	3 weeks	-	5.04 mmol/L = 90.72 mg/dL	4.98 mmol/L = 89.64 mg/dL
Myette-Côté et al./ 2018/ 2015–2017/ [6]	11	4 days	2	8.4 mmol/L = 151.35 mg/dL	7.6 mmol/L = 136.94 mg/dL

Table 2. Overview of clinical studies on the effects of a low-carbohydrate diet on HbA$_{1c}$ levels in patients with type 2 diabetes

Authors/ Year published/ Time of study	Number of patients and median age	Duration of diet	Type of diabetes	HbA$_{1c}$ pre	HbA$_{1c}$ post
Zainordin et al./ 2021/ 2019–2020/ [12]	14 Age: 57	12 weeks	2	8.8%	7.3%
Dorans et al./ 2022/ 2018–2021/ [10]	75 Age: 59.3	6 months	2	6.17%	5.91%
Chen et al./ 2022/ 2018–2019/ [7]	36 Age: 63.3	18 months	2	8.4%	6.9%
Wang et al./ 2018/ 2015–2016/ [8]	24 Age: 66.79	3 months	2	7.43%	6.8%
Han et al./ 2021/ 2019–2020/ [9]	60 Age: 51.45	6 months	2	7.7%	6.0%
Cai et al./ 2021/ 2018–2019/ [11]	22 Age: 25.36	3 weeks	-	5.30%	5.28%
Duffus et, al./ 2022/ time frame not specified/ [13]	14 Age: 15.5	12 weeks	1	7.9%	8.4%

Table 3. Overview of clinical studies on the effects of a low-carbohydrate diet on fasting insulin levels in patients with type 2 diabetes

Authors/ Year published/ Time of study	Number of patients and median age	Duration of diet	Type of diabetes	Fasting insulin pre	Fasting insulin post
Dorans et al./ 2022/ 2018–2021/ [10]	75 Age: 59.3	6 months	2	30.9 µIU/L = 205 pmol/L	26.9 µIU/L = 186 pmol/L
Myette-Côté et al./ 2018/ 2015–2017/ [6]	11 Age: 48–72	3 × 4 days with 9–14 days between each intervention	2	9.3 µIU/L = 64.8 pmol/L	8.94 µIU/L = 62.1 pmol/L

comes outlined in one of the studies suggest that a very low-carbohydrate diet in patients with diabetic kidney disease is not only a safe option but may also be associated with significant improvements in glycemic control. This phenomenon was not observed in the group following a standard low-protein diet [12]. In another study, individuals with DM, who had been assigned to a low-carbohydrate diet, were instructed to consume not more than 25% of their total daily caloric intake from carbohydrates. It turned out that during the trial none of these participants adhered to this recommendation – they went from consuming 44.3% to 44.2% of energy from carbohydrates. Not surprisingly, there were no significant differences in glycemic control, lipid profile, or quality of life parameters. This trial aimed to assess the impact of a low-carbohydrate diet on glycemia, lipidemia, and quality of life but instead it outlined the problem of non-compliance with the instructions by participants. These results are immensely helpful with the realization of how poorly some adolescents follow their doctor's orders [13].

In general, as a result of a low-carbohydrate diet the decrease in fasting glucose levels was observed in all included studies, with an average reduction of 1.16 mmol/L = 20.88 mg/dL. A similar phenomenon was observed for another parameter, which was the fasting insulin level – the average decrease was 10.85 pmol/L. In one study, there was an observed increase in HbA$_{1c}$ (7.9%–>8.4%) among patients with type 1 diabetes. There is a distinct possibility that it happened due to the patients' non-compliance with dietary instructions. In the remainder of the included studies, the average decrease in HbA$_{1c}$ was 0.935%.

Discussion

Principal findings

The outlined outcomes indicate that implementation of a low-carbohydrate diet positively affects glycemic management in both the short and long term [7, 6]. Interestingly, a low-carbohydrate diet may have more beneficial effects on glucose management than a diet based on low-glycemic index products [6]. Moreover, reducing carbohydrate intake might help decrease elevated HbA$_{1c}$ levels without the use of medications [10]. There is a strong possibility that it could also have a greater effect on lowering body weight than physical exercise in patients with T2DM [11]. Interestingly, despite its higher fat and protein content, a low-carbohydrate diet may be more effective in reducing HbA$_{1c}$ levels in patients with diabetic kidney disease than a low-protein diet [12]. However, other diets, such as a low-fat diet, result in a significantly better lipid profile, so special attention has to be paid to assessing individual needs and priorities in therapy [8]. It needs to be emphasized that even the best individually designed treatment may prove ineffective due to, as studies show, patients' common tendency to disregard the recommendations, which especially concerns adolescents [13].

Comparison with previous studies

According to the rule "first, do no harm", the potential risks of low-carbohydrate diets and their possible impact on medical conditions are first addressed. To do that, the results of previously conducted studies are referred to and analyzed. Firstly and most importantly, a Japanese study proved that a low-carbohydrate diet does not increase

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the risk of developing type 2 diabetes. A strong point of this analysis is the significant number of individuals included, which totaled 19,048 [14]. Moreover, diets characterized by a low carbohydrate intake is inversely associated with the risk of diabetic neuropathy in women [15]. On the contrary, previous use of this diet may result in more detrimental oral glucose tolerance test values in women with gestational diabetes mellitus [16]. In the context of type 1 diabetes, one study conducted in an Australian population showed a significant reduction in HbA_{1c} due to the restriction of carbohydrates [17]. This type of diet is also associated with a lower risk of mortality among adults with T2DM, as shown in a study carried out with 5,677 patients [18]. Evidence also suggests that a low-carbohydrate diet may not only influence the physical state but can also lead to an improvement in psychological health in adults with T2DM according to one of the studies which enrolled 115 individuals [19]. Various forms of low-carbohydrate diets exist; one notable example is the ketogenic diet, which is based on the restriction of the consumed carbohydrates to the maximum level. The findings of a recent study show that individuals with T2DM who followed a ketogenic diet could reduce their intake of insulin and antidiabetic drugs, which is highly beneficial [20]. The lifestyle intervention in individuals at high risk of developing type 2 diabetes, while maintaining a relatively carbohydrate-rich diet, resulted in the long-term prevention of progression to type 2 diabetes and is generally seen as safe [21].

Limitations

The primary limitations of the sources analyzed in this study arise from weaknesses in research design. There is a limited number of longitudinal studies with long-term follow-up periods. Additionally, many studies did not include a large enough number of patients and the duration of the trials varied considerably.

Conclusions

A decrease in fasting insulin, fasting glucose, and HbA_{1c} was observed in all studies included in this review that involved patients with type 2 diabetes mellitus. An increase in HbA_{1c} reported in one of the studies with T1DM patients was likely the result of the patients' non-compliance with dietary instructions. These outcomes indicate that a diet low in carbohydrates might be beneficial for diabetics. However, it is crucial to provide patients with clear dietary guidance and then monitor their adherence. Some individuals may not be sure about the allowed products and due to the lower variety of products they may also struggle with cooking ideas. Thus, it seems to be a good idea to recommend dietary consultation in this group. Moreover, calculating macronutrient content for every single meal is a formidable challenge which patients have to face. However, there are specific smartphone applications designed to help monitor calories and nutritious intake from products, which may immensely simplify the process and consequently lead to better dietary compliance. Nevertheless, despite the positive and promising outcomes of this review, further studies, especially with long follow- up periods and a representative number of participants, are required to clearly and explicitly determine all benefits and risks associated with the use of low-carbohydrate diets among patients with diabetes mellitus.

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