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REVIEW ARTICLE

The use of low-carbohydrate diet in type 2 diabetes – benefits and risks

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Abstract

The pharmacological treatment of type 2 diabetes is increasingly being supported by the recommendation of an appropriate diet. The purpose of this study is to identify the potential benefits and risks arising from the use of one of the modern models of low-carbohydrate diet in patients with type 2 diabetes. Research shows that diet can favourably affect the health of diabetic patients. It has been shown that diet affects positively the concentration of blood glucose, glycosylated haemoglobin, and also contributes to the reduction of insulin taken in the course of drug therapy. At the same time, short-term studies have demonstrated a positive relationship of nutrition with reduction in body weight, as well as favourable changes in lipid profile of HDL cholesterol and levels of triglyceride. Attention is also drawn to the negative health effects of a low-carbohydrate diet; these include an increased risk of mineral deficiency, hypovitaminosis and reduced intake of dietary fibres. This diet may be associated with very high levels of protein which, in turn, raises the risk of renal dysfunction and the appearance of irregularities in the water and electrolyte balance. The impact of changes in the skeletal system and the development of osteopenia and osteoporosis is also observed. Besides the positive impact of this model of diet on the lipid profile parameters, its use significantly increases the risk of adverse changes in other markers predisposing to atherosclerosis occurring in individuals with type 2 diabetes. In composing a nutrition model for diabetes patients, both the benefits and potential risks of a low-carbohydrate diet should therefore take into account. At the same time, it is important to individualize the diet used, based on the current state of health, used pharmacological treatments, as well as taking into account the individual characteristics of the patient.

Key words

diabetes type 2, low-carbohydrate diets, high-protein diet

INTRODUCTION

Type 2 diabetes is characterized by a chronic metabolic disorder associated with relative insulin deficiency arising as a result of the secretion defect and / or insulin resistance. Today, the disorder is classified as a civilization disease and its incidence continues to increase. In 2000, the number of patients with type 2 diabetes worldwide was 175 million [1]. It is estimated that by 2030 this number will increase to 336 million patients [2]. Currently in Poland, there are at least 1.6 million people with the illness, representing 5.6% of the Polish population.

Type 2 diabetes usually occurs after 30 years of age, and its development is accompanied by numerous metabolic defects, such as hyperglycaemia and disturbances in the metabolism of lipids and proteins. Hyperglycaemia is the cause of intensification of the processes gluconeogenesis, glycogenolysis and lipolysis, thereby increasing the concentration of acetyl-CoA; the excess is converted into ketone compounds. In addition, excessive synthesis of triglycerides and cholesterol in the liver increases the release of lipoproteins into the bloodstream. In patients with type 2 diabetes an increased concentration of low density lipoprotein (LDL), and intensified the processes of oxidation and glycation of these molecules is observed. Characteristic is the intensification of the production of lipoproteins of very low density (VLDL) in the liver, with decreased activity of lipoprotein lipase, as well as reducing high density lipoprotein (HDL). These disorders, and severity of coexisting protein glycation and oxidative processes, significantly increase the risk of atherosclerosis. The changes in protein metabolism associated with diabetes rely on the intensification of the processes of proteolysis, slowing of protein synthesis, reducing the effectiveness of inward transport of amino acids associated with the process of ketogenesis. It is stressed that the most important factor contributing to the development of diabetic complications is the process of glycation of proteins. This process is subject, among others, to haemoglobin in the form of HbA1c, an important indicator of glycaemic control.

In connection with the identified metabolic abnormalities in type 2 diabetes, selection of diet leveling these disorders, as well as limiting the development of related complications, is very important. Diet used in the course of this type of diabetes should support the pharmacological regulation of blood glucose, also contribute to maintaining normal blood pressure and permit the maintenance of optimal or reduced body weight [3].

The purpose of the presented study is to verify the current state of knowledge concerning usage of low-carbohydrate diets in type 2 diabetes, and to present the benefits and

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risks associated with the given nutrition in these patients. This objective was achieved by comparing the existing models used in feeding diabetic and healthy subjects, as well as an indication of the impact of low-carbohydrate diets on the basic parameters of the development of type 2 of diabetes, such as: metabolism of carbohydrates, lipids and energy balance.

Basic components of traditional diets and diet used in the course of type 2 diabetes. According to the present Polish food pyramid [4], the traditional diet involves consuming large quantities of carbohydrates in the form of whole grains and no grain cereal products. Simultaneously, dietary recommendations include a significant amount of fruits and vegetables. At the top of the pyramid are the foods rich in protein and fats. Experts also attribute an important role to daily physical activity. A properly composed diet should contain specific nutrients, such as carbohydrates, proteins and fats in appropriate proportions. Currently, it is suggested that the content of carbohydrates should be 50–65%, proteins 10–15%, and fat not more than 30% [5].

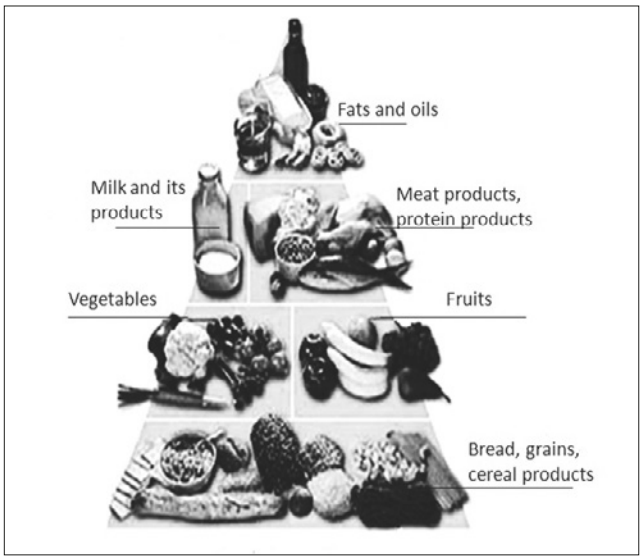

Figure 1. Food pyramid for people with diabetes according to the American Diabetes Association [6]

The food pyramid developed by the American Diabetes Association for diabetics (Fig. 1) [6] only slightly differs from the Polish food pyramid for the general public. Current recommendations by the Polish Diabetes Association suggests that carbohydrates should provide 45–50% of energy from consumed meals, while the European and US standards determine the need for 45–65% of these components in the diabetic diet. This is because of their positive impact on the regulation of blood glucose, maintaining a normal body weight and lipid profile in diabetic patients. This applies especially carbohydrates from foods rich in fibre, such as vegetables or whole grain cereals [3]. Standards for the consumption of saturated fat and cholesterol in the diet of diabetic and traditional diet are not significantly different. Also, the optimal protein content of the diabetic diet, as in the traditional diet, should be within 10–20% of the energy value of meals, which is particularly important in the prevention of nephropathy, where the intake of protein is recommended. To summise, the recommendations on the percentage of each nutrient in the traditional diet and the diet allocated for diabetes are similar. However, it is worth noting that the frequency and regularity of meals is essential. Simultaneously, the application should consider dietary needs of individuals of both nutrients in people with diabetes, as well as in healthy individuals. In patients with type 2 diabetes, the use of a so-called low-carbohydrate diet is quite often considered. This term refers to several types of diets, differing in carbohydrate, protein and fat content (Tab. 1).

Table 1. Examples of low-carbohydrate diets

Type of diet	Content (%) of nutrients
Atkins Diet	3–16% – carbohydrates 28–64% – protein 55–65% – fats
Kwasniewski's Diet	9.2% – carbohydrates 14% – protein 76.8% – fats
Zone Diet	40% – carbohydrates 30% – protein 30% – fats

Source: Own calculations based on [7]

The term 'low-carbohydrate' is not precisely defined. The authors of original works indicated separately define the term both in the amount of carbohydrates consumed during the diet, as well as other nutrients. In the Wylie-Rosett study [8] on such a low- carbohydrate diet, the carbohydrate intake is assumed at 20–60 g/d. Dyson [9] defines each type of diet, in which the carbohydrate content is less than 50g/day, as low-carbohydrate, while Westman [10] indicates that the current type of diet includes carbohydrate content in the range of 50–150 g/d. At the same time, it should be noted that in many works the original amount of each nutrient intake during the diet is analyzed and expressed as a percentage of daily energy needs, making it difficult to clearly compare the results with of analysis using nomenclature based on the weight coefficients.

Regardless of the variant of the diet and the degree of reduction of carbohydrate, deficiency of energy related to their low intake is replaced by proteins or fats. Thus, a low-carbohydrate diet can be used in several ways. There are low-carbohydrate- high-protein diets, among which the most popular is the Atkins diet, and Kwasniewski's low carbohydrate-high-fat diet (Tab. 1). The first, published in 1973, seeks to reduce the consumption of carbohydrates, and at the same time, a large consumption of protein and fat as the main sources of energy [11]. This assumes an intake of carbohydrates in the amount of 7–56 g/d, which represents 3–16% of energy needs, and protein within the limits of 71–161 g/d, i.e. 28–64% of the body's energy needs. In Poland, the low carbohydrate Kwasniewski diet aroused great interest in which 9.2% of energy comes from carbohydrates. In comparison with the Atkins diet, it assumes a higher percentage of fat, the main source of energy, i.e. 76.8% of energy needs and 14% energy from proteins [11, 12]. Despite the considerable popularity for some low carbohydrate diets, their impact on human health is not fully defined.

Effect of low-carbohydrate diet on parameters of carbohydrate metabolism, lipid and energy balance in type 2 diabetes. The results of studies on the effect of low carbohydrate diets in patients with type 2 diabetes are

unclear. Many of the existing studies contain the results of non-randomized and short-term analysis, making it difficult to draw firm conclusions.

In patients with type 2 diabetes, control of glycaemia is a fundamental parameter which must be regulated pharmacologically, and this effect is also achieved through the use of an appropriate diet. Treatment of type 2 diabetes includes not only taking oral anti-diabetic agents, but also the administration of insulin injections. Research indicates that a low-carbohydrate diet can lead to a significant reduction in the units of administered insulin, or cessation or reduction of doses of drugs administered during oral therapy of type 2 diabetes [13, 14, 15, 16]. According to Daly [17, 18], the application of this model allows a reduction of the supply of insulin by up to 85%, compared to that taken before the start of the diet. A similar effect was observed in a low-carbohydrate diet for the treatment of type 2 diabetes with oral anti-diabetic drugs [19]. The nutritional model decreased levels of insulin and glucose in the fasting state and during a 24-hour measurement, but increased the insulin sensitivity of tissues [20, 21]. This had a significant influence on the reduction of body fat and increase of fat-free body mass, which was observed both in obese patients, as well as in those with normal weight [22].

As an important diagnostic parameter in assessing the risk of complications of type 2 diabetes, the measurement of HbA1c is considered. In most cases, the use of a low-carbohydrate diet has a positive impact on this parameter, which indicates the proper control of glucose [21]. The percentage of carbohydrates in the diet known as low-carbohydrate may play an important role in regulating blood glucose levels. Favourable changes in glycosylated haemoglobin were observed in the case of a feeding regimen applying sugars in an amount covering only 25% of daily energy needs, while there were no such changes to the diet containing carbohydrates in the amount of 55% of daily energy needs [14]. The beneficial effects of a low-carbohydrate diet on the level of HbA1 confirm the meta-analysis of Kirk [23].

Abnormalities in the lipid profile are one of the problems occurring in the course of type 2 diabetes. As already mentioned, excessive synthesis of cholesterol and triglycerides in the liver increases the level of atherogenic lipoproteins released into the blood. The following can be observed: increased levels of low density lipoprotein (LDL) and of very low density lipoproteins (VLDL), while reducing the concentration of high-density lipoproteins (HDL). These disorders are often associated with both the pathology of diabetes as well as the so-called 'metabolic syndrome' which may arise in the course of type 2 diabetes. Atherogenic dyslipidaemia significantly increases the risk of cardio-vascular diseases. Chronic hyperglycaemia with abnormal lipid profile has been linked to the processes of glycation, oxidation, methylation and tyrozylation, causing chronic inflammation. Selection of an appropriate diet significantly affects the plasma lipid profile. It is assumed that a low carbohydrate diet containing high fat content should not be recommended for either healthy individuals or patients with type 2 diabetes, due to the increased risk of atherosclerosis. It has been shown that a model of low-carbohydrate nutrition may favourably affect the plasma lipid profile in patients with type 2 diabetes [10, 13, 15, 23, 24, 25] (Tab. 2). This is probably related to lower blood insulin levels in these patients so that it activates hydroxymethylglutaryl lyase – CoA (HMG-CoA reductase), responsible for the synthesis of ketones and the inhibition of HMG-CoA reductase, thus reducing cholesterol synthesis in the liver [26]. It is concluded that the relatively low content of carbohydrates in the diet can contribute to maintaining normal glucose levels, thus indirectly impacting favourably on some lipid parameters and corrects abnormalities observed in type 2 diabetes.

One of the symptoms associated with type 2 diabetes, excess weight, is a co-occurrence of type 2 diabetes, but obesity is relatively uncommon. This indicates the strong relationship between impaired insulin action and fat metabolism. The latter is responsible for the secretion of substances such as fatty acids, hormones and cytokines, which may affect the development of insulin resistance observed in patients with type 2 diabetes [27]. Traditional methods of treatment of obesity involve diet, which significantly reduces the number of calories. This way of feeding involves the supply of energy in the form of nutrients in the following proportions: 10–20% protein, 50–60% carbohydrates, 10–30% fat, which is therefore slightly different from the traditional assumption of rational diet. For fast weight loss, more frequently, more attention is frequently paid to the use of other varieties of diet. These include low carbohydrate diets that cause rapid loss of body weight in a short period in obese patients (Tab. 2).

The effectiveness of the above-diets results not only from the number and sources of energy supplied in the diet, but also in the process of increased diuresis induced by a low-carbohydrate diet. Carbohydrates stored in the body in the form of glycogen in the liver and muscles are burned with the use of water, which causes a rapid loss of water. At the same time, water is eliminated with ketone bodies. In a limited intake of carbohydrates as the main energy source, fatty acids are used. As a result of the accumulation of ketones, such as acetone, acetone-acetic acid and beta-hydroxybutyrate, is observed. There is a chronic state of ketosis, which is an important factor affecting the appetite [11]. A low-carbohydrate diet used by patients with diabetes promotes fast weight loss [9]; however, data comparing the effects of these diet in these patients are unclear. The previously-mentioned meta-analysis by Kirk, comparing the impact of low-carbohydrate diet on weight loss, have not confirmed the beneficial effects of the low-carbohydrate diet for weight loss in patients with type 2 diabetes. Individual studies, including those concerning the effects of low-carbohydrate diet compared with a diet of low glycemic index, have shown a faster weight loss in people with type 2 diabetes [10]. Moreover, the previously-mentioned analysis of Gutierrez, Robertson and Broome, Boden and Yancy and Nielsen, show significant reduction in body weight due to the use of low-carbohydrate diet, compared with the weight of the patients before the diet. It has been suggested, that such a diet increases weight loss in patients with type 2 diabetes, especially in the first period of its duration. In the long-term, studies demonstrate that the effectiveness of this diet on weight loss is similar to the effects of other diets, such as a low-fat diet.

In addition, the two-week low carbohydrate diet in patients with type 2 diabetes reduced concentrations of insulin and leptin and increased the concentration of ghrelin [13]. Similar effects were observed in the long-term use of nutritional obese model. In the case of leptin, the biggest changes were observed in men [20].

Table 2. Comparison of selected studies on effect of low carbohydrate diets used by patients with type 2 diabetes

Study author	Duration of tested diet	Carbohydrate count on tested diet/day	Quantity of FAT in tested diet/day/limits	Favourable changes in HbA1c	Favourable changes in profile of lipids	Influence on body weight
Gutierrez et al.,1998	8 weeks	25% of daily energy demand	30% of daily energy demand	+	No data	+
Robertson & Broom, 2002	12 months	≤ 40g	No data	+	No data	+
Boden et al., 2005	14 days	21g	No restrictions	+	TRIGL ↓	+
Yancy et al., 2005	4 months	≤<< 20	No restrictions	+	TRIGL ↓	+
Nielsen et al., 2006	6 months	75-95g	Fats represent 50% of energy demands by the daily intake of 600-1800 kcal	+	HDL ↑	+
Westman et al., 2008	24 weeks	≤ 20g	No data	+	HDL ↑	+

+ – positive impact; ↑ – increase; ↓ – decrease; TRIGL – triglycerides; HDL – high density lipoprotein

Studies using animal models have demonstrated a slowing of tumour proliferation in the case of low carbohydrate diets. This is due to the fact that glucose metabolism provides appropriate amounts of ATP, necessary for tumour proliferation [28]. Reduction of fat mass on a diet may be important in the case of hormone-dependent cancers (breast, ovary), which often accompany obesity in women with excessive body weight due to an increase in estrogen levels (due to the severity of the conversion of androgens by aromatase in adipose tissue), without increasing the concentration of gestagens. Estrogens are responsible for the higher production of free radicals, which are one of the mutagenic agents. In addition, increased cancerogenesis is correlated with the occurrence of hyperinsulinaemia, insulin resistance and elevated plasma concentration of cytokines (IL-6, TNF-α), produced by excessive amounts of body fat in diabetic patients [29].

Menaces arising from the use of low-carbohydrate diet in patients with type 2 diabetes. Despite the identified benefits of different modifications of low-carbohydrate diet in type 2 diabetes, attention should be paid to existing threats appearing both in the short-term and long-term use of this model of nutrition. A low-carbohydrate diet is deficient and may be the cause of hypovitaminosis [11]. This results from lower participation in the described diets, compared with a traditional or diabetic, fruit and vegetables, the main sources of vitamins, among others antioxidants. This is detrimental for healthy people, and especially for diabetic patients.

A worrying consequence of low carbohydrate diets is the deficit in vitamin C. Type 2 diabetes is associated with oxidative stress and limiting the supply of this compound may further deepen the existing imbalance of antioxidant-oxidation system. Another important negative factor is the shortage of polyphenols, including flavonoids, whose action in the case of normalizing glucose metabolism has been confirmed [30, 31]. It has been shown that supplementing the low-carbohydrate diet with extracts of polyphenols (including flavonoids) and antioxidants (vitamin C) in patients with type 2 diabetes increased the total plasma antioxidant status, decreased lipid peroxidation, and improved the lipid parameters (increase of HDL and lowering LDL fraction of cholesterol), compared to the prior three-month study [31]. It is therefore recommended considering the application of vitamins, especially since the shortage of vegetable fibre in the diet may adversely affect the development of intestinal microflora, responsible, among others, for the production of B vitamins [25]. The fibres (soluble fraction) are of particular importance in the diet of patients with type 2 diabetes because they slow carbohydrate absorption in the intestine, thus preventing large fluctuations in blood glucose and insulin levels. In addition, they reduce the absorption of cholesterol, thereby lowering its concentration in the blood. The use of low-carbohydrate diets with a significantly lower dietary supply of fibres may result in impaired intestinal transit and, consequently, lead to constipation and the initiation of cancer in the colon. In view of the shortage of vegetable fibre in the diet, supplementation of that component is recommended in patients remaining on a diet [32].

Consuming excess protein in the low-carbohydrate / high-protein diet increases the probability of renal dysfunction. This indicates a higher concentration of urea in the blood of people with type 2 diabetes and diet with restriction of saccharides, compared to values recorded in patients before the start of this diet regimen [13, 16].

The above data, concern a low-carbohydrate / high-protein diet for a short time; therefore, it is difficult to predict the long-term effects of this diet [9, 33]. In addition, ketosis occurs and an excess of proteins in the diet promotes hyperuricaemia, which enhances the progression of nephropathy [30]. It is emphasized that the reduced protein intake may slow decline in glomerular filtration and inhibit further damage of kidneys, which is important for people with type 2 diabetes who are frequently associated with nephrological complications. It is worth noting that in these patients, a limit of protein intake to 0.8 g/kg/day is recommended. This covers the amount of protein of less than the 10% of needed energy [34].

Consumption of products low in carbohydrates and high percentage of protein can lead to deficiencies in water and electrolyte balance. Deficiency of calcium, magnesium, potassium and copper, with an excess of sodium, phosphorus, iron and zinc in the blood, are frequently observed [35]. The main reason for these disparities is a disorder of acid-base balance, resulting from the deficiency in the diet of vegetables and excess animal proteins rich in sulfur amino acids. Their metabolite is sulfuric acid, which lowers the pH of urine and promotes the formation of a negative balance of calcium and magnesium. A short-term low-carbohydrate diet causes adverse changes in bone turnover and the formation of osteopaenia and osteoporosis [9, 36, 37]. The indicated dependence is particularly important for postmenopausal diabetic patients in whom a low carbohydrate diet accelerates bone loss. The observed calcuria is also associated with a higher probability of kidney stones [9, 26].

Three days of application of low-carbohydrate diets showed reduced levels of potassium in the blood, which required supplementation of this element [8]. In the elderly, the consequence of hypomagnesaemia was arrhythmia,

hypertension and increased mortality due to heart failure. In addition, changes in the ECG, indicating the adverse effect of ketosis on cardiac function, are observed in patients taking a low-carbohydrate diet [30]. The development of hypertension by low-carbohydrate diet consuming persons also occurs, but persistent high concentrations of iron in the blood led to the deposition of this mineral in the internal organs and their impairment of their functions [38].

It is worth noting that the use of stored carbohydrate, which is muscle glycogen, decreased glycolytic capacity of the body and caused pain and muscle weakness in the case of long-term intake of low-carbohydrate diet. In connection with the high affinity to glycogen, water excretion and increased diuresis caused dehydration. Existing ketosis also intensified these processes [25, 30]. The consequence of glycogen depletion on the low-carbohydrate diet is the risk of hypoglycaemia. It should be emphasized that the provision of large amounts of amino acids in the body, even in low-carbohydrate products, stimulates an increase in blood insulin levels [30]. Thus, hypoglycaemia is more common in patients with type 2 diabetes treated with insulin or its analogs. To prevent this, it is important that a correct dosage of drugs is determined by frequent analysis of glucose and insulin levels, and transmission of information about making low-carbohydrate diet to the medical staff [8].

Despite the previously-described benefits of some lipid parameters in a low-carbohydrate diet, particularly high-fat / high-cholesterol reduction of fibre was associated in some patients with an increase in LDL in the blood, both in patients with type 2 diabetes [24] and in those without disturbances of carbohydrate [11, 22]. The lipid profile appears to be an insufficient parameter to assess the risk of atherosclerosis. In some obese patients, LDL in the blood was reduced by a low-carbohydrate diet and increased size of lipoprotrein and reduced their density, thus increasing the risk of cardiovascular problems. It is also worth noting that the annual observations by the obese showed increased blood levels of other prognostic markers of atherosclerosis: lipoprotein a, fibrinogen and homocysteine [39, 40]. A low-carbohydrate / high-fat diet also increased the level of C-reactive protein (CRP) and interleukin 6 (IL-6), indicating the severity of adverse effects of inflammation [41].

The described nutrition in patients with excessive body weight did not normalize high levels of oxidized LDL in the blood, indicating a continuing high risk of cardiovascular complications [22]. A non-invasive study of arterial 'stiffness' showed abnormalities within the vascular endothelium in the case of eating low-carbohydrate diet, as opposed to people using a low-fat diet model [42]. In addition, in some patients, low levels of total cholesterol in the diet with carbohydrate restriction for a period of several weeks was observed, but has not been confirmed in a 12-month analysis, indicating the transient nature of these changes [40].

The use of low-carbohydrate diet / high-fat and / or high protein, rich in red meat, especially in males is controversial. A 20-year study, with measurements repeated periodically every four years, conducted among more than 40,000 subjects, indicated that the model did not augment the risk of developing type 2 diabetes in the case of all respondents, but raised the risk in men before 65 years of age [43]. A similar study conducted among more than 80,000 women, showed that the mentioned diet did not increase the incidence of glucose intolerance [44]. It is worth noting that the supply of fat and vegetables as protein, as opposed to animal products, had a beneficial role in the prevention of type 2 diabetes [43].

Eleven years of studies with about 23,000 Greek obese patients (including those with impaired glucose metabolism) showed a 22% increase in risk of death overall in chronically consuming low-carbohydrate products / high-protein, compared to other models of feeding [45]. Many years of studies in a large research group (over 42,000 Swedish women) confirmed the increase in mortality (11%), caused a 37% increase in deaths from cardiovascular causes in a low-carbohydrate but high-protein diet [46]. In addition, the 20-year prospective cohort study conducted on 130,000 people have demonstrated that the consumption of animal products increased by 23%, and a diet rich in vegetables decreased overall mortality by 20%, while the number of deaths from cardiovascular causes decreased by up to 23% [47]. It seems that in addition to macro-components, important sources of individual components of the diet are also important. Food of animal origin, as the main source of homocysteine and saturated fats, may be the main cause of the disadvantages of the use of low-carbohydrate diet. Regardless of the variant high in fat or protein, of importance is the separation of diets based primarily on animal products from those based on ingredients of plant origin.

CONCLUSIONS

The use of a low-carbohydrate diet in type 2 diabetes is associated with the need to assess the effects of short-and long-term consumption of foods low in nutrients which are simple and complex saccharides. Available studies, conducted by global research centres, indicate the beneficial effects of this model of diet only in a relatively short period of its use. Special attention must be paid to the possibility of effective weight reduction for people with type 2 diabetes and obesity coexisting simultaneously. However, it should be noted that while short-term use of this dietary pattern has a positive effect on anthropometric parameters, long-term consumption of low amounts of saccharides, similar to other diets, affect the reduction of excess of body weight. The consumption of low-carbohydrate foods also has a positive impact on the regulation of glucose levels, reducing the amount of insulin taken, and concentration of glycosylated haemoglobin. In addition, experimental results mention the positive impact of a low-carbohydrate diet on the plasma lipid profile, particularly at the level of triglycerides and HDL cholesterol in the blood of people with type 2 diabetes.

The benefits of diets poor in saccharides are not in doubt; however, they are complicated by the possibility of adverse effects. A diet based on the exclusion of specific foods increases the risk of mineral deficiencies and the phenomenon of hypovitaminosis. Particular risks are connected with B vitamins and vitamin C. A similar situation is observed in the case of lack of fibre, together with the lack of carbohydrates; a low carbohydrate diet with high intake of protein is considered to be a predictive factor for kidney damage. A high intake of protein, while maintaining a low supply of carbohydrates, can also lead to disturbances in fluids and electrolytes, and changes in bone turnover, responsible for the development of osteopenia and osteoporosis.

The previously-mentioned positive effects of low-carbohydrate diet on lipid parameters are reduced by

independent clinical studies, indicating the possibility of increased LDL cholesterol and markers predisposing to atherosclerosis in patients with type 2 diabetes. Finally, analysis based on representative groups of obese patients, including disorders of carbohydrate metabolism, showed an increase in mortality from cardiovascular diseases in the long-term use of a diet low in saccharides.

In considering the positive and negative aspects of low-carbohydrate diet in patients with type 2 diabetes, it should be noted that to date no conclusive results proving the impact of this one-way model of nutrition has been proved.

The composition of a model of nutrition for diabetic patients should therefore be guided by the need to compensate blood glucose levels, and other parameters specific to diabetes, but attention must be paid to the individualization of the used diet, attention to the regularity of meals and adequate physical activity based on the current state of health, pharmacological methods of used treatment, as well as intra-individual characteristics of the patient.

It should especially noted that the previously-defined dietary regimens designed for patients with type 2 diabetes (so-called 'diabetic diet') and / or obese people, in terms of the percentage of each nutrient in the diet, are only slightly different from the recommended regimen in healthy individuals.

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