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Health consequences of using special diets with restricted carbohydrate consumption

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ABSTRACT

Introduction and purpose: There are many reasons why patients with specific health disorders, as well as people in good health, decide to follow special diets. Often their choice falls on dietary models that include limited carbohydrate intake. The most popular in this area are low-carbohydrate and high-protein diets, which have a significant impact on metabolism, making them of particular interest to people with excessive body weight.

State of knowledge: Low-carbohydrate diets include many dietary models of varying restrictiveness, with or without achieving a state of ketosis. The ketogenic diet has the most promising clinical results in terms of effects on carbohydrate and fat metabolism. Long-term studies are still too few and inconsistent, also regarding the effects on weight loss compared to traditional approach.

High-protein diets also include a reduction in carbohydrate intake, but with a higher proportion of protein in the total diet energy content. Observations on the effect of weight reduction and metabolic modification are inconsistent. The possible multi-directional negative health effects seem to be a strong argument against this approach and its recommendation.

Conclusion: The basis of any reduction diet must be a reduced energy supply. This can be achieved in a variety of ways, which are designed to facilitate its implementation by patients, as well as to have the most beneficial effect on their impaired metabolism. Diversions from the traditional approach may have beneficial effects, but may also contribute to other health problems. It is important to consider the patients' health status as a whole, and to ensure specialist follow-up when using described special diets, because of possible side effects and difficulties in properly balancing the diet. They can only be recommended in specific cases, with a protein-rich diet appearing particularly dangerous. The standard in the management of excessive body weight remains the traditional approach, the effects of which are well documented and do not represent risk factors for other conditions.

Key-words: special diets; low-carbohydrate diet; high-protein diet; weight loss

INTRODUCTION AND PURPOSE

The essential role of a well-balanced diet is to provide the body with the nutrients it needs to function. These include carbohydrates, plant and animal proteins, fats and vitamins and minerals as well as other bioactive substances. A standard diet is defined as a diet that fully meets the needs within a given community, using available dietary resources [1].

There are situations, in which modifications of the basic diet are introduced on purpose, consisting in the elimination of certain product groups, the resignation from certain food processing methods or changes in the macronutrient ratio. In such cases we deal with an alternative diet, which is a diet that differs from the usual one [1, 2].

A number of different purposes of introducing an alternative diet can be distinguished. These include:

- Reducing body weight – low calorie diets
- Health-promoting and well-being-enhancing effects
- Following the principles resulting from the worldview one follows (philosophical, ethical, religious, ecological) – mainly vegetarian diets of varying degrees of restrictiveness
- Supportive treatment of various diseases and disorders – specific recommendations in the field of diet therapy
- Method of therapy in food intolerances – gluten-free, lactose-free diets [2]

In a situation where it is necessary to adapt the diet to the specific requirements of the organism conditioned by its physiological or pathological state, we talk about the use of a therapeutic diet. By definition, a therapeutic diet is designed to have a therapeutic function by modifying the intake of certain nutrients and/or the consistency of meals. Such a diet is aimed at protecting the diseased organ, meeting the increased demand for specific macro- and microelements due to health disorders, as well as limiting the supply of compounds that may aggravate the disorder or are intolerated by the patient. Then, it provides a properly composed diet, which becomes an element of the therapy of the disease and is essential for maintaining proper functioning and improving the patient's quality of life. However, another group of people who decide to follow alternative diets are healthy individuals. It should be noted that every diet, in order to fulfill its basic function, which is proper nourishment of the system, should fully cover the individual's demand for all the essential nutrients. Among alternative diets, we often find diets that are difficult to balance by people without proper education, or even diets that basically are unbalanced and require pharmacological support in the form of individually tailored supplementation. It is not uncommon for consumers to be unaware of this fact, leading to nutritional deficiencies that potentially threaten the health and lives of these individuals [2, 3, 4].

The most popular alternative diets used by both sick and healthy individuals are low-carbohydrate - high-fat and high-protein diets [1, 2].

LOW-CARBOHYDRATE DIET

The basic concept of a low-carbohydrate diet is, as the name suggests, to limit the supply of carbohydrates. Depending on how much restriction we have to deal with, low carbohydrate diets can be divided into very low, low or moderate content of carbohydrates. They range from 20-50 g/day (<10% of dietary energy), <130 g/day (<26% of dietary energy) or 26-45% of dietary energy, respectively [5]. Low carbohydrate intake is defined as the level at which ketosis does not yet occur. It is determined by the presence of ketone bodies in blood and urine, which are synthesized if the diet has a very low carbohydrate supply [5].

The essence of this alternative approach to diet is the metabolic changes occurring on its account in the body, which are characteristic of the state of starvation, i.e. ketosis. The organism facing glucose deficiency switches into the mode of saving it as an energy substrate for the needs of the whole metabolism. The preference for the use of possible energy sources is altered, as a result of which ketone bodies are oxidized first instead of glucose. As a result, insulin secretion decreases and lipogenesis is inhibited. The stimulation of lipolysis results in the synthesis of ketone bodies which are an energy substrate for mitochondria [2, 5].

It should be emphasized that 130 g of carbohydrates is the minimum recommended amount of carbohydrates for proper functioning of glucose dependent tissues such as brain, red and white blood cells and kidney cortex. However, in light of metabolic studies, it is apparent that under conditions of excessively low glucose intake, these tissues are able to adapt at least partially to metabolize fat [5].

Robert Atkins is considered the progenitor of low-carbohydrate diets, even though he was not the original creator. The Atkins diet, also known as the optimal diet, is based on an extreme restriction of carbohydrates to 3-10% of the diet's energy or 20-50g per day, while increasing the intake of protein and fats, which are allowed in unlimited amounts, usually making up 50-60% of the diet's energy. It is applied in 4 stages. Initially, the goal is to put the body into a state of ketosis by limiting the supply of carbohydrates to 30g per day for a period of 2 weeks. These are provided exclusively by non-starchy vegetables. Then, after the body weight is reduced and the system adapts to the reduced supply of glucose, it is gradually increased to 5g of carbohydrates a week until the body weight stabilizes on a constant level. The next 2-3 months is a time of expanding the diet with vegetables and fruits in individually selected amounts - in order to maintain the achieved weight loss. The last stage, maintenance, is permanent and consists in maintaining the carbohydrate intake at a defined level with constant control of weight and lipid profile [2, 5, 6].

The group of diets with a limited supply of carbohydrates also includes the paleo diet, which has become fashionable in recent years. This diet is supposed to reproduce the dietary model of our ancestors who lived during the Paleolithic era, who consumed only food that was hunted or gathered by them. Due to the exclusion of grain processing, grain products are not relevant in this diet. Therefore, the only sources of carbohydrates are some fruits and starchy vegetables. The paleo diet is instead rich in various kinds of meat, fish, eggs, nuts and vegetables [5].

There is also an extremely low-carbohydrate ketogenic diet, which is a separate model of nutrition. It involves limiting the supply of carbohydrates to 10% of the total energy supply or less than 50g per day. At the same time, it maintains an adequate amount of protein as required. This is a method of therapy that entered the standard of management of drug-resistant epilepsy in children almost a century ago. It is also used in the treatment of inborn metabolic defects and neurodegenerative diseases and, due to the growing popularity of this approach, its effect on the development of type 2 diabetes, polycystic ovary syndrome, and cancer is being studied [5, 7].

In recent years, low-carbohydrate diets have become the subject of much research into their effects on general health, as well as their use in the treatment of specific disease entities.

There are still not enough publications describing the results of interventions on large population groups to assess the long-term effects of these diets and to draw well-founded conclusions, not to mention the development of specific recommendations. Although there are many studies showing promising results of this type of dietary model in areas such as weight reduction, reduction of blood levels of triglycerides, or improvement of peripheral tissue insulin sensitivity, there are legitimate concerns about recommending them. Significantly, the trials performed so far do not allow a clear assessment of whether the beneficial changes in metabolism and their effects in the test results are a consequence of the onset of ketosis or an accompanying effect of weight reduction itself, in which the ketogenic diet is definitely helpful. Another limitation that prevents definite conclusions is that the effects of low-carbohydrate diets in general have been studied without taking into account the control of maintaining a state of ketosis, which may significantly affect the results [5, 7, 8].

Weight reduction

With a carbohydrate energy supply of less than 20 g/day, the body produces ketone bodies, which are used by the brain as an energy source, resulting in a feeling of satiety and promoting dietary compliance. The induced anorectic effect results in a reduced energy supply. Low-carbohydrate diets are further characterized by a high proportion of protein, which also has a high satiety index. Low carbohydrate diet model has a positive influence on patients' hunger control and thus may facilitate weight loss [1, 9, 10, 11].

On the other hand, weight loss with the described model of nutrition consists mainly of water loss from the body. Due to carbohydrate deficiency in the diet, glycogen is released from hepatocytes and myocytes. Since there are 2 grams of bound water for every gram of it, these losses are significant [1, 12, 13, 14, 15].

The proponents of low carbohydrate diets emphasize that limiting the carbohydrate supply in the diet results in lowering the insulin concentration, which is responsible for fat deposition in the body. However, it is known that meals with a varied composition have a different effect on gastric emptying rate and insulin response. Attributing the responsibility for weight gain exclusively to insulin is not scientifically proven [1, 7]. So far, the effect of ketogenic diet on weight reduction has not been clearly explained; however, it is probably a complex mechanism involving several simultaneous processes in the body [7]. Reduced carbohydrate supply results in increased intensity of gluconeogenesis, which leads to increased daily energy expenditure of the patient by approximately 400-600 kcal [16]. The influence of diet on the control of hunger and satiety is also frequently raised. Hormonal changes, involving increased cholecystikinin faculty and reduced ghrelin, combined with the action of synthesized ketone bodies and an increase in circulating FFAs produce the described appetite-inhibiting effect [7, 17]. Although these mechanisms are desirable in the context of obesity treatment, other groups of patients to whom low-carbohydrate diet is often recommended - those with cancer and neurodegenerative diseases - should be kept in mind. In their case, appetite suppression can be extremely dangerous as they are at risk of malnutrition due to increased catabolism and anorexia occurring for other reasons [7].

In addition, the initial period of ketogenic diet is associated with impaired gastrointestinal function due to excessive fat intake. The consequence may be the occurrence of nausea, vomiting and obstruction [18].

Many observations confirm the beneficial effect of limiting the carbohydrate intake on the effectiveness of weight reduction at the beginning of the diet [19], however, the long-term effects of the reduction do not differ from other dietary models [11, 20].

A 6-month follow-up by Brehm et al. showed better patient outcomes in terms of weight loss with a low-carbohydrate diet compared to a low-fat diet. Moreover, there was no deterioration in parameters that may contribute to cardiovascular risk in the study group [13].

However, the data after one year of the reduction diet are contrasting. Long-term effects of patients on low-carbohydrate and conventional diets do not differ [21].

Similar results were obtained in the study by Foster et al. comparing low-carbohydrate and low-fat diets in terms of reduction effectiveness. In this case, again, after 3 and 6 months, they were better in patients on a carbohydrate-restricted diet, while after 1 year, the body weight indications were the same in both groups [9]. Reports of no effect on improving long-term weight loss outcomes when using a low-carbohydrate diet instead of a standard low-calorie diet are supported by the results of many researchers [22, 23, 24].

The meta-analysis from 2008 comparing low-carbohydrate diets (daily intake of carbohydrates < 60g) to low-fat diets also showed that people following KD, after 6 months showed greater weight reduction than those in the other group, while after 12 months there were no statistically significant differences between the diets [25].

A 2012 meta-analysis comparing the effectiveness of low-fat and low-carbohydrate diets overall on weight reduction found no differences between them [26]. Given the evidence for the high efficacy of ketosis-inducing diets in this regard, it is possible to speculate that it is not the reduction of carbohydrate supply per se, but the achievement of this state that is responsible for accelerating weight loss [7].

It has also been shown that weight and body fat loss depend more on the energy deficit itself and the length of the diet than on the restriction of carbohydrate intake [1, 27, 28].

The study by Sacks et al. compared reduction diets with the same energy restriction while reducing the supply of various macronutrients - protein, fat and carbohydrate. In all groups, the effects after both 6 months and 2 years of diet were similar [20].

Effects on lipidogram

In the context of metabolic changes, it is important to consider the effects of diet on carbohydrates and lipidogram [7].

During the initial period of low-carbohydrate diets, a change in the proportion of cholesterol fractions in favor of HDL and a decrease in the concentration of LDL and triglyceride fractions are observed, especially when the diet evokes a state of ketosis. However, with long-term use of the diet, increases in triacylglycerols and total cholesterol have also been reported, by up to 26% compared with the mixed diet. The deterioration of parameters that are risk factors for atherosclerosis - total lipidogram and fibrinogen concentration - is usually noted in studies. [1, 11, 13, 29].

Some reports show a reduction in blood insulin levels in patients on a low-carbohydrate diet and cholesterol levels on a low-fat diet as early as 10 weeks [30].

A meta-analysis of long-term, at least 12-month studies, published in 2013, comparing the effects of low-carbohydrate and low-fat diets on overweight and obese individuals showed greater reductions in: body weight, blood triacylglycerol levels, and diastolic blood pressure, as well as increases in HDL and LDL cholesterol levels, in individuals assigned to the KD groups compared to participants on the LFD [31].

A study by Fung et al. showed an association of low-carbohydrate diets with an increased risk of death in individuals with no medical conditions such as diabetes, heart disease or cancer. However, the quality of fat in the diet was crucial in this regard. When only animal sources were used, total deaths, deaths from cardiovascular disease, and deaths from cancer increased. The case was reversed with the use of plant sources of fat, as a decrease in deaths from all causes was recorded in this group of patients [32].

A new approach to the ketogenic diet, combining it with the principles of the Mediterranean diet, deserves special attention. A 12-week Spanish variant of the ketogenic diet showed promising results in the observation of 22 obese and metabolic syndrome patients on parameters such as LDL, triglycerides, fasting blood glucose, blood pressure, waist

circumference, BMI and body weight. The reduction occurred despite the absence of imposed energy restrictions [7, 33].

Effects on carbohydrate metabolism

Given the key role of carbohydrates in inducing postprandial glycemia, it might seem a logical approach to limit their intake in order to reduce blood glucose and insulin secretion in diabetics. An additional benefit of a low-carbohydrate diet in these patients would also be the accompanying loss of excess body weight, a risk factor for the disease [7]. There is scientific evidence that low-carbohydrate diets are effective in the treatment of diabetes by lowering glycemia, even resulting in the need to reduce the dose of hypoglycemic drugs [8, 34]. However, it is difficult to determine the usefulness of ketosis in diabetes therapy due to the very small number of observations described. They are conducted not only on small groups of patients, but also for a short period of time. The long-term effects of their use are still unknown. An important reason for this is the serious health risk to patients and the fear of hypoglycemia and ketoacidosis due to such intervention [35].

Nutritional deficiencies

Furthermore, the scarcity of low-carbohydrate diets is a concern due to the specificity of allowed and prohibited products. It is based on high-calorie, high-fat animal products, and plant-based foods are largely contraindicated. Low-carbohydrate diet is therefore poor in vitamins, especially B vitamins: thiamine, riboflavin, niacin, vitamin B6, folate, biotin, pantothenic acid and antioxidants. It also contains too few minerals, such as potassium, calcium, magnesium, zinc and selenium, as well as flavonoids. In order to balance it properly, an appropriate supplementation is necessary [1, 7, 11, 36].

The dietary fiber supply is also insufficient, which promotes constipation and gastrointestinal dysfunction [1].

The so-called optimal diet was recognized in 2002 by the Therapy Committee of the Polish Academy of Sciences as being extremely harmful to health due to its characteristic excessive supply of cholesterol, retinol and iron with simultaneous deficiency of vitamin C, potassium, calcium and magnesium [36].

Excessive supply of sodium and phosphorus as well as retinol and iron due to high intake of cured meats and meat and highly processed products may lead to dysfunction of the nervous system and cell membrane functions, and liver damage. Thus, chronic use of low-carbohydrate diets may increase the risk of kidney disease, liver disease, osteoporosis and cardiovascular disease, and may even be life-threatening [1].

Patients following this dietary model should be under constant monitoring for hypotension, dizziness, chronic fatigue, gout, and renal failure [5].

It can be concluded that the effectiveness of low-carbohydrate diets in the context of weight reduction is based, like any weight-loss diet, on a reduced caloric supply relative to the body's needs [28].

HIGH-PROTEIN DIET

This model of nutrition is based on increasing the proportion of protein in the total energy content of the diet to 30-40%. It belongs to the group of protein and fat diets. Its most popular variant is the Dukan diet, which is conducted in 4 stages. Initially, in the shock phase, for about a week patients can eat only products that are a source of protein, mainly animal, both low in fat and providing a large amount of saturated fatty acids and cholesterol. The next stage is called the alternating phase and consists of taking the products from the first stage varied with the addition of some vegetables for 1-5 days and only protein products for another 1-5 days. This cycle is repeated until the desired body weight is achieved. The third phase - consolidation, is based on protein products for 1 day a week, while on the other days it is allowed to include 1 portion of fruit, cereal products, hard cheese and 2 portions of vegetables. The length of this phase depends on the effects of the reduction and is equal to 10 days for

each kilogram of weight lost. The last stage is the stabilization phase, followed for the rest of the patient's life. In this phase, the patients are free to compose their diet, but for one day a week they eat only protein products [1, 37, 38].

The effectiveness of the described nutritional model, similarly to high-fat diets, is associated with the occurrence of ketosis and utilization of fatty acids as the source of energy for the central nervous system [1, 38].

The dietary protein delays gastric emptying and reduces the gastrointestinal motility. Peptides formed from the digestion of protein-rich products increase the number of receptors and sensitivity to leptin, while increased blood amino acid concentrations and increased postprandial thermogenesis inhibit the hunger center and stimulate the satiety center in the hypothalamus [1].

Dietary protein has beneficial effects on peripheral regulation. It decreases both tissue insulin- and leptin resistance, without increasing fasting ghrelin levels, and increases glucagon levels, among others, resulting in increased gluconeogenesis, lipolysis and thermogenesis and decreased VLDL synthesis in the liver and lipogenesis in adipose tissue. As a result, satiety is increased, appetite is inhibited and food intake is reduced, and lipid profile, glucose and insulin levels are normalized. Increased protein metabolism leads to increased thermogenesis, which in turn may cause an additional effect of inhibiting appetite, increasing basal and total metabolism, by boosting the rate of protein turnover process, enhancing fat-free mass, which prevents a decrease in basal metabolism and maintenance of muscle mass during weight loss [1].

Risk factors for metabolic syndrome

The adverse changes occurring in people following this model of nutrition should also be emphasized, especially because protein-rich diets are preferred by individuals wishing to quickly reduce body weight. The problem of overweight or obesity very rarely occurs on its own. Usually it coexists with various metabolic abnormalities, which are part of the diagnostic picture of the metabolic syndrome. Moreover, even if such disorders are not yet present, excessive body weight is one of the main risk factors predisposing to their development. Therefore, the dietary approach to weight reduction should also take into account the effects on parameters such as glycemia, lipidogram or blood pressure for their treatment or prevention [39].

Effects on the excretory system

Consumption of protein-rich diets for long periods of time can lead to increased glomerular filtration rate, which in turn leads to intraglomerular hypertension and deterioration of renal function. The fundamental basis of dietary therapy for related conditions is to limit the supply of protein to unburden the organ. Therefore, a serious contraindication to the Dukan diet is an abnormal GFR level and diagnosed kidney disease. Moreover, particularly disadvantageous in the context of nephrological complications, as well as aggravating the progression of diabetes, is the high consumption of meat, which is the basis of the described dietary model [1, 39, 40].

Although studies do not show the influence of protein diet on the impairment of glomerular filtration rate in healthy subjects, it is also worth considering other disorders related to the excretory system. The diet-induced increase in calcium, urate and phosphate excretion may increase the risk of kidney stones [39, 41].

The increased glomerular filtration rate causes also the increased loss of calcium from urine, which promotes the development of osteoporosis. In addition, acid-base balance is disrupted due to high protein supply, which also enhances calcium mobilization from bone [42, 43].

As a result of the breakdown of excess purines, serum uric acid concentration increases significantly, which exacerbates the course of gout. It is also a contributing factor to

the development of atherosclerotic plaques in the arteries and hypertension. Thus, it is a predisposing factor for ischemic heart disease [1, 38, 39, 44].

The deficiencies of dietary fiber, vitamins A, E, D, B1, B2, folate, magnesium and the excessive supply of sodium and phosphorus are also frequently observed in subjects consuming high-protein diet [1].

An insufficient supply of dietary fiber characteristic of the Dukan diet has multidirectional negative effects on the body. As far as the effects experienced by patients are concerned, the occurrence of constipation and, consequently, an increased risk of colorectal cancer should be stressed [38].

High-protein diets should be used with prior medical consultation because there are many groups of conditions for which they will be contraindicated. These include liver and kidney dysfunction, in which dietary recommendations suggest a diet in which only 10% of the total daily energy supply should come from protein because of the associated reduction in the production of ammonia and urea, which have a debilitating effect on these organs. In the context of harmful effects on the excretory system, the high phosphate content of the Dukan diet should also be highlighted [38].

Effects on the cardiovascular system

Despite the beneficial effect of high-protein diets on lipidogram observed in short-term trials, it can be assumed that it was mainly due to a greater decrease in body weight than in the case of classical macronutrient distribution [17]. It is worth noting that the increase of protein supply in relation to carbohydrates, with a constant amount of fat in the diet, has no effect on improving the results in terms of weight loss, as well as on the levels of total cholesterol and its individual fractions, but only on lowering the concentration of triglycerides [45, 46, 47].

A 12-year follow-up of a group of 42,237 women aged 30-49 years showed that consumption of a low-carbohydrate protein diet was associated with an 11% higher mortality rate. This increase was due to a 37% increase in cardiovascular deaths [48].

These reports are also confirmed by a 2007 cohort study that reported a 22% increase in the risk of total death with chronic low-carbohydrate high-protein diet [49].

Due to the lack of long-term observations to assess the effectiveness and safety of these diets and inconclusive results of clinical trials, they should not be recommended as a method of treatment of obesity or related civilization diseases. The recommendations of scientific societies use safe and well-studied dietary models based on control of dietary energy value, whose long-term effectiveness in terms of weight reduction does not differ from the results of protein diets [1, 38].

CONCLUSION

A diet based on general principles of proper nutrition should not only be the starting point for composing a menu for everyone who wants to take care of their health, but also the basis for building modifications for all therapeutic diets. In the context of weight reduction, these consist, in the conventional approach, of reducing the energy content of the diet and limiting the intake of sugars and fat – including saturated fatty acids. This is a well-recognized method of treating overweight and obesity with documented effectiveness. It should be remembered, that the basis of any reduction diet must be a reduced energy supply.

Low-carbohydrate diets may help patients maintain adequate energy balance and thus improve weight loss outcomes. However, as far as the effects of these diets on metabolic disorders and diseases associated with obesity are concerned - both in the case of protein-rich and fat-rich diets - the research so far does not allow to draw clear conclusions. However, it is known that such an approach to nutrition is associated with a high risk of nutritional deficiencies, which can lead to many serious health complications. Another issue is the difficult to escape high content of saturated fatty acids, in the case of which all

recommendations suggest a significant reduction. Particularly relevant here is the issue of cardiovascular complications. Overweight and obesity are both conditions that increase interest in low-carbohydrate diets and also risk factors for metabolic syndrome elements. Thus, more long-term observational studies on large population groups are needed to draw clear conclusions and recommendations. As far as healthy subjects are concerned, the multitude of contraindications and possible complications, as well as the necessity of supervision by a specialist in order to appropriately balance the described diets, are the factors on the basis of which they can be considered as not advisable as a daily diet without clinical indications.

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