Arh. farm. 2024; 74: 281 – 297 *Review article/Pregledni rad*

Dietary interventions in obesity: a narrative review

Olina Dudašova Petrovičova[1*], Ivana Đuričić[1], Nevena Ivanović[1], Nevena Dabetić[1], Margarita Dodevska[2], Tijana Ilić[1]

[1]University of Belgrade – Faculty of Pharmacy, Department of Bromatology, Vojvode Stepe 450, 11221, Belgrade, Serbia

[2]Institute of Public Health of Serbia "Dr Milan Jovanović Batut", Center for Hygiene and Human Ecology, 11000 Belgrade, Serbia

*Corresponding author: Olina Dudašova Petrovičova; e-mail: olina.dudasova@gmail.com

Received: 15 April 2024; Revised in revised forme: 1 June 2024; Accepted: 9 June 2024

Abstract

The World Health Organization highlights that in 2022 around 890 million adults and 160 million children and adolescents globally were obese, indicating a significant public health concern. Obesity results from an energy imbalance, where calorie intake exceeds calorie expenditure, leading to an increase in the size of fat cells and subsequently to metabolic dysfunction and inflammation. Management of obesity involves lifestyle adjustments, including dietary modifications and increased physical activity, with calorie-restricted diets and meal replacements often recommended to achieve weight loss and lower overall energy intake. Weight loss programs include a low-carbohydrate, low-fat, or high-protein diet. In addition, the influence of the Mediterranean diet and dietary fiber on regulating body weight has been increasingly studied in recent years. Dietary products for weight control, including meal replacements, are regulated and offer options for people who want to lose weight. More personalized nutrition approaches are emerging that focus on individual needs, genetic factors and gut microbiota composition to optimize health outcomes. Although personalized nutrition promises to explain how nutrition-related health problems may be solved, further research should investigate health outcomes in individuals living with obesity.

Key words: obesity, dietary intervention, personalized nutrition

https://doi.org/10.5937/arhfarm74-50457

Introduction

According to the World Health Organization, around 890 million adults aged 18 years and older worldwide were living with obesity in 2022, while this number reached 160 million among children and adolescents in the same year (1). In Serbia in 2019, more than half of the population (57.1%) aged 15 and over were overweight, including 36.3% pre-obese and 20.8% obese individuals (2). Obesity is closely related to an excessive accumulation of fatty tissue throughout the body, which occurs primarily when energy intake from high calorie foods continuously exceeds energy expenditure (calories burned). As a result, excess calories are stored in adipose tissue, increasing the size (hypertrophy) and number (hyperplasia) of fat cells (adipocytes) (3). The enlargement of adipose tissue in obesity leads to changes in its function and metabolism, and contributes to the development of metabolic disorders and systemic inflammation. Adipose tissue produces various hormones and cytokines, known as adipokines, which regulate energy balance, appetite, insulin sensitivity, and inflammation (4). Dysregulation of adipokine secretion in obesity can lead to insulin resistance, chronic low-grade inflammation, and metabolic syndrome. Excess visceral fat is particularly harmful as it is metabolically active and strongly associated with an increased risk of metabolic disorders, cardiovascular disease, and other obesity-related health complications (5). Management of obesity often involves strategies to reduce adipose tissue through lifestyle modifications, including dietary changes, increased physical activity and behavioral interventions. In the era of new drugs for obesity, dietary approaches are still of great importance. A calorie-restricted diet is recommended as the first-line treatment for obesity in most relevant guidelines. Generally, reducing daily energy intake by approximately 500 calories is often associated with a weight loss of around 0.5 kg per week or 2 kg per month (6). This reduction in calories is usually achieved by controlling portion sizes and reducing fats and refined carbohydrates, while increasing the intake of protein and fiber from plant foods. These dietary adjustments aim to lower the overall energy density of the diet. In addition to a structured diet plan or weight loss program, meal replacements have also been developed to provide controlled amounts of calories, nutrients, and portion sizes to support weight management goals. The aim of this article is to discuss current dietary patterns that are effective for weight loss and the long-term effects of adherence to dietary interventions in obesity.

Types of Dietary Interventions

Dieticians and health professionals have developed various nutritional plans to achieve the desired reduction in body mass. Many of these plans have focused on reducing calorie intake, specifically modifying macronutrient intake. According to the Dietary Guidelines and Nutrient Reference Intakes, adults should obtain 45% to 65% of their total calories from carbohydrates, 25% to 30% from fats and 12% to 15% from proteins (7). Some diets alter this ratio by increasing the intake of certain macronutrients over others. Another important aspect is the source of food, with a plant-based diet being preferable (8) (Figure 1).

Figure 1. Types of dietary interventions in obesity
Slika 1. Vrste dijetarnih intervencija kod gojaznosti

Low Carbohydrate Diet

A low carbohydrate diet (LCD) has been recognized as a promising approach in the treatment of obesity over the last decades. The main feature of this diet is the reduction of carbohydrates and the increase of fat intake. There is no strict definition of the ratio between fat and carbohydrate intake; usually, very low carbohydrate diet indicates approximately 50 g or less of carbohydrates (CH) per day (i.e., 10% of total calories), while moderate LCD indicates about 40% of calories from carbohydrates (9). A stringent reduction of carbohydrates in the diet (ketogenic diet) leads to increased beta-oxidation of fatty acids, providing a large amount of acetyl-CoA, which is further converted into ketone bodies (KB): acetoacetate (AcAc), β-hydroxybutyric acid (BHB) and acetone (10), becoming the dominant source of energy for vital organs. There is no consensus on the long-term effectiveness of the LCD diet compared to a low-fat or calorie-restricted diet. Meta-analyses of randomized controlled trials (RCTs) reported that LCD was associated with a significant decrease in body weight (effect size: - 0.70 kg; 95% CI: -1.07, -0.33; $p<0.05$) and fat mass (effect size: -0.82 kg; 95% CI: -1.22, -0.42; $p<0.05$). However, diet programs lasting over 12 months showed that LCD only led to a significant reduction of adipose tissue (effect size: -0.57 kg; 95% CI: -1.05, -0.09; $p<0.05$), with no differences in body mass loss (effect size: -0.44 kg; 95% CI: -0.94, 0.07; $p>0.05$) compared to control diets (9). The lower percentage of adipose tissue in body composition indicates a positive effect of long-term LCD on maintaining lean body mass. In addition, a recent review and meta-analyses of the ketogenic diet with limited calorie intake (500-800

kcal/day) have shown significant short-, medium-, and long-term weight loss and positive changes in body composition parameters, as well as glycemic and lipid profiles (11). This diet significantly reduced body weight (effect size: -7.06 kg; 95% CI: -11.16, -2.97; p = 0.0007), waist circumference (effect size: -8.33 cm; 95% CI: -11.34, -5.33; p < 0.00001), fat mass (effect size: -9. 35 kg; 95% CI: -13.29, -5.4;1 p < 0.00001), total cholesterol (effect size: -7.13 mg/dL; 95% CI: -9.71, -4.55; p < 0.00001) and triglycerides concentrations (effect size: -29.90 mg/dL; 95% CI: -42.47, -17.32; p < 0.00001), and improved insulin resistance measured by the HOMA-IR index (the Homeostatic Model Assessment for Insulin Resistance) (effect size: -1.36; 95% CI: -2.14, -0.57; p < 0.00001), compared to other weight loss interventions over the same period. The significant reduction in HbA_1c, blood glucose, and LDL cholesterol was similar to other weight management programs (11). The main concern associated with LCD is its impact on the lipid status, due to its high fat content. Recent studies suggest a positive effect of LCD on blood lipid levels, leading to a reduction in triglycerides and an increase in HDL levels. The impact on the LDL fraction was inconsistent; some studies reported a change in LDL-cholesterol type from small LDL to large LDL cholesterol, which is considered to be less atherogenic (11, 12). Besides health benefits, there are some common side effects of LCD, including gastrointestinal disorders, transient hypoglycemia, dehydration, hyperuricemia, halitosis and adverse changes in lipid levels (11). Generally, this dietary approach should be carried out under medical supervision, emphasizing a controlled intake of saturated fats of animal origin, either for a shorter period (up to one year) or longer (10).

Low Fat Diet

A low-fat diet (LFD) has been recommended as the primary weight-loss diet. The main advantage of this diet type is reduced fat intake. Like in LCD, the ratio of main macronutrients is not strictly defined; LFD typically contains less than 30% and very-LFD ≤20% of fat, and the dominant energy source are carbohydrates, including calorie restriction (13). The type of carbohydrates included in the diet is essential. A low-fat diet carries the risk of high consumption of refined carbohydrates with a high glycemic index, strongly associated with the onset of insulin resistance and diabetes. Therefore, carbohydrates from whole grains, non-starchy fruits and vegetables, legumes and other high-fiber foods with low glycemic index are preferable in LFD. Research suggests that a low-fat diet with a higher fiber intake may improve glycemia, body weight and insulinemia in obese individuals (14). In addition, high fiber content provides satiety and gastric distension and triggers satiety signals (15). In a meta-analysis of the long-term effects of dietary interventions on weight loss in adults, a low-fat diet resulted in a more significant weight loss than the regular diet (effect size: -5.41 kg; 95% CI: -7.29, -3.54; p<0.05), but had no benefits compared to other moderate fat weight loss dietary interventions (effect size: 0.36 kg; 95% CI: -0.66, 1.37; p>0.05). Low-carbohydrate dietary interventions led to a significantly higher weight loss than low-fat interventions (effect size: 1.15 kg; 95% CI: 0.52, 1.79; p<0.05) (16). Compared to the LCD, the LFD positively affected total cholesterol and LDL cholesterol levels, offering cardioprotective benefits in obese patients (17).

High Protein Diet

Dietary proteins are indispensable macronutrients that, among other physiological functions, are crucial for tissue formation, growth, enzyme and hormone synthesis. The recommended protein intake varies according to age, gender, and physiological needs, with healthy adults generally being recommended to consume 0.8 g/kg body weight (18, 19). Animal and plant sources provide dietary proteins with different amino acid profiles, structures, and digestibility. Animal foods (meat, fish, eggs, dairy products) provide well-balanced amino acids, essential minerals (zinc, iron) and vitamins (B_{12}, D), as well as good digestibility, which classifies them as high-quality proteins. On the other hand, dietary guidelines are increasingly advocating a plant-based diet (legumes, nuts and seeds) due to concerns about the disease risks and environmental impact associated with animal products. Even though plant-based foods have an unbalanced amino acid composition and are lower in quality and digestibility compared to animal sources, combining different plant sources can provide protein quality comparable to animal sources while offering better health and environmental benefits (18, 20).

Recent clinical studies have focused on the effects of high protein consumption (HPD), particularly in individuals with obesity. It is suggested that HPD may promote weight loss by enhancing satiety through increased concentrations of anorexigenic hormones (e.g., glucagon-like peptide 1, peptide tyrosine-tyrosine and cholecystokinin) and decreased concentrations of the orexigenic hormone ghrelin. Additionally, HPD may counteract obesity through increased food-induced thermogenesis, amino acid concentrations, gluconeogenesis and ketogenesis (21). On the other hand, there is some concern about the adverse effects of HPD (22). While a prior review outlined the negative impacts of HPD on bone and kidney health, encompassing heightened resorption and risk of bone fractures, osteoporosis, kidney stones, and a potential link to cancer and liver function impairments (23), other studies did not find this correlation (21).

Mediterranean Diet

The Mediterranean diet (MD) is widely accepted as the most effective among other plant-based diets and refers to the eating habits of the people living around the Mediterranean Sea (24). However, the Mediterranean diet is not an exclusive model, and it varies among the Mediterranean regions. In general, this plant-based diet is characterized by a high consumption of vegetables, fruits, legumes, cereals and nuts, as well as olive oil as the main source of fat. Fish, eggs and poultry are consumed in moderate quantities, while the consumption of sweets, red meat and dairy products is very low (25).

Epidemiological studies have confirmed an inverse correlation between adherence to the Mediterranean diet and weight gain/body mass index (26). In the MedWeight study, higher adherence to the Mediterranean diet has been associated with a higher likelihood of losing weight (27). However, most studies did not consider the effects of energy intake or the impact of physical activity. A systematic meta-analysis of 16 RCTs confirmed the importance of these two factors associated with the Mediterranean diet in achieving the

goal (28). It is concluded that weight loss is more pronounced in cases where physical activity is included and energy intake is reduced (effect size: -4.01 kg; 95% CI: -5.79, -2.23, $p<0.05$ and -3.88 kg; 95% CI: -6.54, -1.21, $p<0.05$, respectively) than the effect of Mediterranean diet alone compared to a control diet (effect size: -1.75 kg; 95% CI: -2.86, -0.64, $p<0.05$) (28). One of the largest RCTs showed that an unrestricted-calorie, high-vegetable-fat MD was not associated with significant weight loss, but resulted in lower central adiposity compared to a low-fat diet (29). The positive effect of the MD on reducing central obesity is likely related to the high intake of unsaturated fatty acids and low intake of saturated fatty acids (30). In addition, the MD implies a high intake of dietary fiber (about 33 g per day), which reduces hunger and increases satiety more than a diet with low fiber intake (31). The low energy density of the MD reduces total energy intake. Some studies have shown that the moderate alcohol consumption (red wine) recommended in the MD contributes to weight loss, but the evidence is not yet conclusive (25).

Adherence to the MD decreased significantly between 1960 and 2011 (32). A comprehensive systematic review recently found that MD adherence mainly depends on the socioeconomic status and geographic location. Slightly higher adherence to the MD was observed in European countries (33). One study showed that higher adherence was related to education, non-smoking and physical activity (34). Considering all the health benefits of MD mentioned above, there is a great need for educational programs to establish healthy eating habits, especially among specific populations.

High dietary fiber diet

One of the reasons for the effectiveness of dietary interventions aimed at reducing body weight is the influence of fiber from the recommended diet (whole grains, fruits, vegetables, legumes and nuts). Numerous studies have confirmed that a controlled, high-fiber diet positively affects weight loss (35-37). Dietary fibers are carbohydrate polymers with three or more monomer units that are neither digested nor absorbed in the human small intestine (38, 39). Fibers represent a large number of compounds of different molecular weights, physical properties and physiological effects, which is why there are several classifications. The classification according to the chemical structure (i.e., according to the monosaccharide units contained in the composition of the polymer and according to the type of bond) includes β-glucan, fructan, resistant starch, cellulose, arabinoxylan, chitosan, glucomannan (37). The EFSA recommends >25 g of dietary fiber daily to improve weight maintenance and support weight loss in overweight and obese individuals (40). High-fiber foods, regardless of their physical or chemical properties, have a lower energy density, contribute to a balanced energy intake and prevent weight gain. The influence of total dietary fiber and individual types of fiber fractions is under constant scrutiny, and the usage is steadily increasing. Therefore, dietary fiber should have its rightful place in eating habits as an important part of a healthy and sustainable diet.

Meal replacements

Foods for weight control are a category of foods intended to meet the specific nutritional needs of overweight or obese people in order to lose weight. According to the regulations in the EU and Serbia, these products are defined as specially formulated dietary products with reduced energy value that can replace part of the daily diet or the entire daily diet. They are divided into two categories: 1) products intended as substitutes for a complete daily diet (total diet replacement for weight control); 2) products intended as substitutes for one or more meals during the day (41).

In the EU, this category of foods was introduced in 1998 by Directive 96/8/EC (22). However, the complete replacement of meals for weight control is regulated by Regulations (EU) No. 609/2013 and (EU) No. 2017/1798 as one of the Food for Specific Groups (FSG) categories (42, 43). These regulations do not apply to meal replacements, which fall under the general food law regulation. In Serbia, these two categories are regulated by a single regulation, namely the Rulebook on the safety of dietary products (41). The current regulation strictly defines the composition of these products so that the products must reach the daily nutritional requirements of healthy, overweight or obese adults as part of an energy-restricted diet for weight loss, as determined based on generally accepted scientific data. The regulations contain strict requirements on the amount of energy, the amount and quality of protein, the amount and type of fat, the minimum and maximum levels of dietary fiber and the minimum levels of certain vitamins and minerals. These requirements are listed in the Table I.

Table I Macro- and micronutrient requirements for food for weight control (41)

Tabela I Propisana količina makro- i mikronutrijenata u hrani za kontrolu telesne težine (41)

	Total meal replacement (EU requirements) *	**Meal replacement**
Energy	800-1200 kcal (600-1200 kcal) *	200-400 kcal
Proteins	25-50% of product energy value, max 105 g (75–105 g) *	/
Lipids	< 30% of product energy value ≥ 11 g linoleic acid per day* ≥ 1.4 g α-linolenic acid per day*	/
Fibers	10-30 g	
Vitamins/minerals	≥ 100% of defined Nutrition Reference Value (≤ 250 mg of magnesium for the total daily ration)	≥ 30% of defined Nutrition Reference Value
Carbohydrates	≥ 30 for the total daily ration.	
Choline*	≥ 400 mg for the total daily ration.	/

* Requirements according to Commission Delegated Regulation (EU) 2017/1798

The guiding principle for strictly defining the composition of meal replacements for weight control is to ensure that these products are safe and appropriate when consumed as the sole source of nutrition by overweight or obese adults for several weeks to months.

Meal replacement products are intended to induce a significant energy deficit in overweight and obese adults who want to lose weight and replace one or more meals or the entire diet as part of an energy-restricted weight-loss diet. The replacement for one or more meals should have an energy content between 200 kcal and 400 kcal. The total meal replacement for weight control should be between 600 kcal (or 800 kcal) and 1200 kcal per day, and it is usually referred to as a low-calorie diet. Products that contain less than 800 kcal and are intended to replace the entire diet are also known as very low-calorie diets (22). They were included in the EU regulations 2022 but are not yet regulated in Serbia. Interestingly, the European Clinical Practice Guidelines for the Treatment of Obesity in Adults (44) state that very low-calorie diets can be part of a comprehensive treatment to reduce body weight if they are carried out under the supervision of a physician specializing in nutrition and dietetics. However, the duration of their use should be limited in certain patients and for a limited time, and they are not suitable as the sole source of nutrition for infants, children, adolescents, pregnant and lactating women, and older people. Studies also show that adherence to a reduction diet based on whole food substitutes is generally higher than that of conventional foods with the same calorie content (45, 46).

For this reason, the following two claims for meal replacements have been authorized based on Regulation (EU) No. 2016/1413 (47) in the EU and Serbia (Rulebook on Nutrition and Health Claims Regulation): 1) “Replacing one of the daily main meals in an energy-restricted diet with a meal replacement helps to maintain weight after weight loss”; and 2) “Replacing two of the daily main meals in an energy-restricted diet with meal replacements contributes to weight loss”.

Weight loss supplements

Food supplements are concentrated sources of various ingredients such as minerals, vitamins, amino acids, metabolites, herbs, and plant extracts. In recent years, these products have proven to be a promising alternative to conventional treatments due to their minimal toxicity compared to pharmaceuticals. Table II shows some of the most frequently used supplements with the mechanism of action against obesity.

Table II Weight loss supplements

Tabela II Suplementi za gubitak telesne težine

Ingredients	Bioactive compounds	Potential mechanisms	EFSA recommendations	Ref.
Coffee	alkaloids (caffeine, trigonelline) chlorogenic acid (5-*O*-caffeoylquinic acid), diterpenes (cafestol and kahweol)	Reduce the activity of key enzymes involved in lipogenesis (acetyl-CoA carboxylase, fatty acid synthase and/or stearoyl-CoA desaturase) and lipid digestion (digestive lipase); Enhance enzymes involved in fatty acid *β*-oxidation (carnitine palmitoyltransferase 1) , lipolysis, energy expenditure, and thermogenesis	400 mg of caffeine/day (equivalent to four 8-ounce cups of brewed coffee)	(48-50)
Bitter orange (*Citrus aurantium*)	phenylethylamines alkaloid (*p*-synephrine), flavonoids (naringin, hesperidin, neohesperidin, limonene)	Inhibit adipogenesis via PPAR*γ* and C/EBP*α*; Promote lipolysis and thermogenesis through AMPK*α* activation; Modulate satiety	10-53 mg synephrine/day	(51-53)
Green tea (*Camellia sinensis*)	catechins (epicatechin, epigallocatechin, epigallocatechin 3 gallate)	Changes gut microbiota composition and decrease nutrient absorption; Reduce appetite by inhibiting ghrelin secretion; Increase thermogenesis inhibiting COMT and phosphodiesterase	Below 800 mg epigallocatechin gallate/day	(54-56)
Chill Pepper (*Capsicum annuum*)	capsaicinoids (capsaicin), flavonoids, carotenoids	Increase satiety and reduce food intake; Modulate gastrointestinal function and gut microbiome, including stimulating GLP-1 secretion and increasing bacterium *Akkermansia muciniphila*. Stimulate of both brown and white adipose tissue, reducing hyperlipidemia; Enhance thermogenesis by increasing catecholamine levels, postprandial energy expenditure, and lipid oxidation	Phenylcapsaicin maximum level of 2.5 mg/day	(56-57)

Table II (continued)

Ingredients	Bioactive compounds	Potential mechanisms	EFSA recommendations	Ref.
Dietary fiber	Glucomannan (*Amorphophallus konjac*)	Prolong gastric emptying time to increase satiety; Decreases intake of foods that increase cholesterol and glucose levels; Suppresses hepatic cholesterol synthesis and increases fecal cholesterol elimination; Reduces appetite, digestion, and nutrient absorption in the gut;	3g/ day	(58-59)
	Chitosan	Increasing leptin concentration and decreasing the expression of the neuropeptide Y gene can increase satiety, leading to a reduction in calorie intake;	Dosages may vary depending on the specific product and formulation	(60-62)

Personalized/Precise Nutrition in Obesity Treatment

Traditional approaches to weight control that focus on general dietary guidelines and one-size-fits-all recommendations, usually based on population averages, may be of little benefit to individuals (63). Indeed, RCTs have shown that only 40% of people respond to diet and lifestyle interventions designed to reduce disease risk in an entire population (64). The limited effectiveness observed with general dietary interventions to combat obesity and its associated complications can be attributed to inter-individual variability influenced by genetics, epigenetics, behavioral and psychological traits, gut microbiome composition, and environmental influences (65). Given the emerging evidence that personalized nutritional approaches are a more effective strategy for improving dietary intake than general dietary recommendations, the concept of personalized or precision nutrition has been established. Two main reasons support the potential effectiveness of personalized nutrition approaches in improving eating behaviors and achieving long-term health outcomes. First, there is a biological rationale for adjusting food intake at the individual level. Second, individualized approaches positively impact motivation and adherence to dietary recommendations (66).

As proposed by Daniel and Klein, personalized nutrition should focus on dietary recommendations tailored to an individual's specific needs and consider both phenotypic and genotypic considerations to maintain health status and prevent risks for disease (67). However, few studies have investigated the effectiveness of personalized nutrition with different approaches in humans. One notable example of research in this area is the Food4Me study, conducted as an RCT including more than 1600 adults in seven European

countries to examine the concept of personalized nutrition (68). The study aimed to determine whether personalized nutrition interventions are superior to conventional dietary recommendations in improving eating behavior. It also aimed to determine which types of information are the most effective in formulating personalized dietary recommendations and whether an internet-delivered dietary intervention can effectively deliver personalized dietary advice. The results showed that personalized nutritional interventions were more effective in producing lasting changes in eating behavior over six months than standardized healthy eating advice. Interestingly, the study also found that including phenotypic and/or genotypic information, a more complicated and costly approach to developing personalized dietary recommendations, did not provide additional benefits.

In recent years, research in personalized nutrition has recognized the central role of the gut microbiota in triggering individual responses to food. There is evidence that the initial composition of the microbiome can influence individual response to diet and that differences in response to dietary interventions related to obesity correlate with specific bacterial species present at baseline. Consequently, the microbiome is a potential target for nutritional interventions, such as precision microbiomics, and serves as a promising biomarker for predicting response to diets and interventions, leading to better prospects in promoting health and preventing disease (65).

However, for personalized nutrition, additional studies are needed to provide information on the factors (psychological, social, economic, etc.) that influence individuals so that they can change their dietary behavior accordingly and maintain these changes (66).

Conclusion

Based on the information presented in this paper regarding current dietary interventions and lifestyle modifications for addressing widespread obesity, it is evident that there is no consensus on the optimal solution. Adherence emerges as a key challenge across various dietary interventions, with better compliance observed in diets based on whole-food substitutes and personalized approaches. Very low-calorie and very low-carbohydrate ketogenic diets show effectiveness for rapid body weight reduction, but their long-term safety remains inadequately supported by evidence. The Mediterranean diet is favorable for sustained weight management over extended periods. Despite the various available weight loss programs, there is an increasing need to educate the population about the importance of adopting healthy eating patterns and including moderate physical activity as the most effective way to prevent obesity and obesity-related health complications.

Acknowledgements

NA

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author contributions

Olina Dudašova Petrovičova: Writing - original draft, Writing - review & editing, Visualization, Data curation; **Ivana Đuričić**: Writing - original draft, Writing - review & editing, Supervision**; Nevena Ivanović**: Conceptualization, Writing - original draft; **Nevena Dabetić**: Writing - original draft; **Margarita Dodevska**: Writing - original draft; **Tijana Ilić**: Writing - original draft, Writing - review & editing, Visualization, Data curation.

References

1. World Health Organisation [Internet]. Obesity and overweight; 2024 [cited 2024 May 25]. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.
2. Statistical Office of the Republic of Serbia [Internet] [cited 2024 May 25]. Available from: https://publikacije.stat.gov.rs/G2021/pdfE/G20216003.pdf.
3. Horwitz A, Birk R. Adipose tissue hyperplasia and hypertrophy in common and syndromic obesity—The case of BBS obesity. Nutrients. 2023;15(15):3445.
4. Kirichenko TV, Markina YV, Bogatyreva AI, Tolstik TV, Varaeva YR, Starodubova AV. The role of adipokines in inflammatory mechanisms of obesity. Int J Mol Sci. 2022 Nov 29;23(23):14982.
5. Chait A, Den Hartigh LJ. Adipose tissue distribution, inflammation and its metabolic consequences, including diabetes and cardiovascular disease. Front Cardiovasc Med. 2020 Feb 25;7:522637.
6. Hwalla N, Jaafar Z. Dietary management of obesity: a review of the evidence. Diagnostics. 2020 Dec 25;11(1):24.
7. EFSA (European Food Safety Authority), 2017. Dietary Reference Values for nutrients Summary report. EFSA supporting publication. 2017:14(12):e15121.
8. Greger M. A Whole Food Plant-Based Diet Is Effective for Weight Loss: The Evidence. Am J Lifestyle Med. 2020 Apr 3;14(5):500-510.
9. Hashimoto Y, Fukuda T, Oyabu C, Tanaka M, Asan M, Yamazaki M, Fukui M. Impact of low-carbohydrate diet on body composition: meta-analysis of randomized controlled studies. Obes Rev. 2016;17(6):499–509.
10. Paoli A. Ketogenic diet for obesity: friend or foe? Int J Environ Res Public Health. 2014 Feb;11(2):2092-107.
11. Muscogiuri G, El Ghoch M, Colao A, Hassapidou M, Yumuk V, Busetto L. Obesity Management Task Force (OMTF) of the European Association for the Study of Obesity (EASO). European Guidelines for Obesity Management in Adults with a Very Low-Calorie Ketogenic Diet: A Systematic Review and Meta-Analysis. Obes Facts. 2021;14(2):222-245.

12. Bueno NB, de Melo ISV, de Oliveira SL, da Rocha Ataide T. Very-low-carbohydrate ketogenic diet v. low-fat diet for long-term weight loss: a meta-analysis of randomised controlled trials. BJN. 2013;110(07):1178–1187.
13. Ludwig DS, Willett WC, Volek JS, Neuhouser ML. Dietary fat: From foe to friend? Science. 2018 Nov 16;362(6416):764-770.
14. Thompson SV, Hannon BA, An R, Holscher HD. Effects of isolated soluble fiber supplementation on body weight, glycemia, and insulinemia in adults with overweight and obesity: a systematic review and meta-analysis of randomized controlled trials. Am J Clin Nutr. 2017 Dec;106(6):1514-1528.
15. Chao AM, Quigley KM, Wadden TA. Dietary interventions for obesity: clinical and mechanistic findings. J Clin Invest. 2021;131(1):e140065.
16. Tobias DK, Chen M, Manson JE, Ludwig DS, Willett W, Hu FB. Effect of low-fat diet interventions versus other diet interventions on long-term weight change in adults: a systematic review and meta-analysis. Lancet Diabetes Endocrinol. 2015 Dec;3(12):968-79.
17. Prentice RL, Aragaki AK, Van Horn L, Thomson CA, Beresford SA, Robinson J, et al. Low-fat dietary pattern and cardiovascular disease: results from the Women's Health Initiative randomized controlled trial. Am J Clin Nutr. 2017 Jul;106(1):35-43.
18. Ferrari L, Panaite S, Bertazzo A, Visioli F. Anima- and plant-based protein sources: A scoping review of human health outcomes and environmental impact. Nutrients. 2022;14:5115.
19. Carbone J, Pasiakos S. Dietary protein and muscle mass: Translating science to application and health benefits. Nutrients. 2019;11:1136.
20. Day L, Cakebread J, Loveday S. Food proteins from animals and plants: Differences in the nutritional and functional properties. Trends Food Sci Technol. 2022;119:428-442.
21. Moon J, Koh G. Clinical Evidence and Mechanisms of High-Protein Diet-Induced Weight Loss. J Obes Metab Syndr. 2020 Sep;29(3):166-173.
22. EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA). Scientific opinion on the essential composition of total diet replacements for weight control. EFSA Journal. 2015 Jan;13(1):3957.
23. Delimaris I. Adverse Effects Associated with Protein Intake above the Recommended Dietary Allowance for Adults. ISRN Nutr. 2013 Jul 18;2013:126929.
24. Keys A. Mediterranean diet and public health: personal reflections. Am J Clin Nutr. 1995 Jun;61(6):1321-23.
25. Schröder H. Protective mechanisms of the Mediterranean diet in obesity and type 2 diabetes. J Nutr Biochem. 2007 Mar;18(3):149-60.
26. Sánchez-Villegas A, Bes-Rastrollo M, Martínez-González MA, Serra-Majem L. Adherence to a Mediterranean dietary pattern and weight gain in a follow-up study: the SUN cohort. Int J Obes (Lond). 2006 Feb;30(2):350-8.
27. Poulimeneas D, Anastasiou CA, Santos I, Hill JO, Panagiotakos DB, Yannakoulia M. Exploring the relationship between the Mediterranean diet and weight loss maintenance: the MedWeight study. Br J Nutr. 2020 Oct 28;124(8):874-880.
28. Esposito K, Kastorini CM, Panagiotakos DB, Giugliano D. Mediterranean diet and weight loss: meta-analysis of randomized controlled trials. Metab Syndr Relat Disord. 2011 Feb;9(1):1-12.

29. Estruch R, Martínez-González MA, Corella D, Salas-Salvadó J, Fitó M, Chiva-Blanch G, et al. Effect of a high-fat Mediterranean diet on bodyweight and waist circumference: a prespecified secondary outcomes analysis of the PREDIMED randomised controlled trial. Lancet Diabetes Endocrinol. 2019 May;7(5):6-17.
30. Muscogiuri G, Verde L, Sulu C, Katsiki N, Hassapidou M, Frias-Toral E, et al. Mediterranean Diet and Obesity-related Disorders: What is the Evidence? Curr Obes Rep. 2022 Dec;11(4):287-304.
31. Howarth NC, Saltzman E, Roberts SB. Dietary fiber and weight regulation. Nutr Rev. 2001 May;59(5):129-39.
32. Vilarnau C, Stracker DM, Funtikov A, da Silva R, Estruch R, Bach-Faig A. Worldwide adherence to Mediterranean Diet between 1960 and 2011. Eur J Clin Nutr. 2019 Jul;72(1):83-91.
33. Damigou E, Faka A, Kouvari M, Anastasiou C, Kosti RI, Chalkias C, Panagiotakos D. Adherence to a Mediterranean type of diet in the world: a geographical analysis based on a systematic review of 57 studies with 1,125,560 participants. Int J Food Sci Nutr. 2023 Dec;74(8):799-813.
34. Marventano S, Godos J, Platania A, Galvano F, Mistretta A, Grosso G. Mediterranean diet adherence in the Mediterranean healthy eating, aging and lifestyle (MEAL) study cohort. Int J Food Sci Nutr. 2018 Feb;69(1):100-107.
35. Reynolds A, Mann J, Cummings J, Winter N, Mete E, Te Morenga L. Carbohydrate quality and human health: a series of systematic reviews and meta-analyses. Lancet. 2019 Feb 2;393(10170):434-445.
36. Dodevska MS, Sobajic SS, Djordjevic PB, Dimitrijevic-Sreckovic VS, Spasojevic-Kalimanovska VV, Djordjevic BI. Effects of total fibre or resistant starch-rich diets within lifestyle intervention in obese prediabetic adults. Eur J Nutr. 2016 Feb;55(1):127-37.
37. Lattimer JM, Haub MD. Effects of dietary fiber and its components on metabolic health. Nutrients. 2010 Dec;2(12):1266-89.
38. Commission Directive 2008/100/EC of 28 October 2008 amending Council Directive 90/496/EEC on nutrition labelling for foodstuffs as regards recommended daily allowances, energy conversion factors and definitions (OJ L 285, 29.10.2008, p. 9).
39. Ivanović N, Ilić T, Zrnić Ćirić M, Todorović V, Đuričić I, Dabetić N. Agri-food by-products as a source of sustainable ingredients for the production of functional foods and nutraceuticals. Arh Farm. 2023;73:190-204.
40. European Food Safety Authority (EFSA). EFSA Panel on Dietetic Products, Nutrition, and Allergies. Opinion on dietary reference values for carbohydrates and dietary fibre. EFSA J. 2010;8(3):1462.
41. Pravilnik o zdravstvenoj ispravnosti dijetetskih proizvoda. Službeni glasnik RS 45/2010-107, 27/2011-47, 50/2012-49, 21/2015-22, 75/2015-22, 7/2017-36, 103/2018-70, 45/2022-360.
42. Regulation (EU) No 609/2013 of the European Parliament and of the Council of 12 June 2013 on food intended for infants and young children, food for special medical purposes, and total diet replacement for weight control and repealing Council Directive 92/52/EEC, Commission Directives 96/8/EC, 1999/21/EC, 2006/125/EC and 2006/141/EC, Directive 2009/39/EC of the European Parliament and of the Council and Commission Regulations (EC) No 41/2009 and (EC) No 953/2009.

43. Commission Delegated Regulation (EU) 2017/1798 of 2 June 2017 supplementing Regulation (EU) No 609/2013 of the European Parliament and of the Council as regards the specific compositional and information requirements for total diet replacement for weight control.
44. Yumuk V, Tsigos C, Fried M, Schindler K, Busetto L, Micic D, Toplak H. European guidelines for obesity management in adults. Obes Facts. 2015 Dec 5;8(6):402-24.
45. Wadden TA, Butryn ML, Byrne KJ. Efficacy of lifestyle modification for long-term weight control. Obes Res. 2004 Dec;12 Suppl:151S-62S.
46. EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA). Scientific Opinion on the substantiation of health claims related to meal replacements for weight control (as defined in Directive 96/8/EC on energy restricted diets for weight loss) and reduction in body weight (ID 1417), and maintenance of body weight after weight loss (ID 1418) pursuant to Article 13(1) of Regulation (EC) No 1924/2006. EFSA Journal. 2010;8(2):1466.
47. Commission Regulation (EU) 2016/1413 of 24 August 2016 amending Regulation (EU) No 432/2012 establishing a list of permitted health claims made on foods other than those referring to the reduction of disease risk and to children's development and health (Text with EEA relevance).
48. Farias-Pereira R, Park C, Park Y. Mechanisms of action of coffee bioactive components on lipid metabolism. Food Sci Biotechnol. 2019;28(5):1287-1296.
49. Haraguchi A, Yamazaki T, Ryan C, Ito K, Sato S, Tamura K, et al. Caffeine suppresses high-fat diet-induced body weight gain in mice depending on feeding timing. J Funct Foods. 2022;99:105307.
50. Alshahrani SH, Atia Y, Badir RA, Almalki SG, Tayyib NA, Shahab S, et al. Dietary caffeine intake is associated with favourable metabolic profile among apparently healthy overweight and obese individuals. BMC Endocr Disord. 2023;23:227.
51. ANSES [Internet]. Opinion of the French Agency for Food, Environmental and Occupational Health & Safety on the Risks Associated with the Presence in Food Supplements of *p*-synephrine or Ingredients Obtained from Citrus Spp. Fruits Containing This Substance [cited 2024 May 25]. Available from: https://www.anses.fr/en/content/opinion-french-agency-food-environmental-and-occupational-health-safety-risks-associated-1.
52. Park J, Kim H, Jung Y, Ahn KS, Kwak HJ, Um J. Bitter orange (*Citrus aurantium* Linne) improves obesity by regulating adipogenesis and thermogenesis through AMPK activation. Nutrients. 2019;11:1988.
53. Guimarães AC, Gaspar de Moura E, Silva SG, Lopes BP, Bertasso IM, Pietrobon CB, et al. *Citrus aurantium* L. and synephrine improve brown adipose tissue function in adolescent mice programmed by early postnatal overfeeding, Front Nutr. 2024;10:1278121.
54. Liu Z, Chen Q, Yhang C, Ni L. Comparative study of the anti-obesity and gut microbiota modulation effects of green tea phenolics and their oxidation products in high-fat-induced obese mice. Food Chem. 2022;367:130735
55. Lin Y, Shi D, Su B, Wei J, Găman MA, Sedanur Macit M, et al. The effect of green tea supplementation on obesity: A systematic review and dose-response meta-analysis of randomized controlled trials. Phytother Res. 2020;34(10):2459-247.
56. Diepvens K, Westerterp KR, Westerterp-Plantenga MS. Obesity and thermogenesis related to the consumption of caffeine, ephedrine, capsaicin, and green tea. Am J Physiol Regul Integr Comp Physiol. 2007;292:R77-R85.

57. Lee H, Song J, Chung S, Cha Y, Han A. Gochujang elicits anti-obesity effects by increasing capsaicin-independent brown adipogenesis and thermogenesis in high-fat diet inducet obese mice. J Funct Foods. 2023;111:105886
58. McRorie JW. Evidence-based approach to fiber supplements and clinically meaningful health benefits, part 1. What to look for and how to recommend an effective fiber therapy. Nutr Today. 2015; 50(2):82–9.
59. Mohammadpour S, Amini MR, Shahinfar H, Tijani AJ, Shahavandi M, Ghorbaninejad P, et al. Effects of glucomannan supplementation on weight loss in overweight and obese adults: A systematic review and meta-analysis of randomized controlled trials. Obes Med. 2020;19:100276.
60. Fatahi S, Sayyari AA, Salehi M, Safa M, Sohouli M, Shidfar F, Santos HO. The effects of chitosan supplementation on anthropometric indicators of obesity, lipid and glycemic profiles, and appetite-regulated hormones in adolescents with overweight or obesity: a randomized, double-blind clinical trial. BMC Pediatr. 2022 Sep 5;22(1):527.
61. Chiu Y-H, Chiang M-T. Development of Chitosan and Its Derivatives as a Dietary Supplement with Anti-Obesity Effect and Their Effects on Lipid Metabolism. Molecules. 2017;22(7):1161.
62. Guo Z, Xing R, Liu S, Zhong Z, Ji X, Wang L, Li P. Advances in Microbial Chitosan Biosynthesis and Its Application. Mar Drugs. 2019;17(9):459.
63. Lau Y, Chee DGH, Chow XP, Cheng LJ, Wong SN. Personalised eHealth interventions in adults with overweight and obesity: A systematic review and meta-analysis of randomised controlled trials. Prev Med. 2020 Mar;132:106001
64. De Roos B, Brennan L. Personalised Interventions-A Precision Approach for the Next Generation of Dietary Intervention Studies. Nutrients. 2017 Aug 9; 9(8):847.
65. Djordjevic B, Ivanovic N. Precise Nutrition and Metabolic Syndrome, Remodeling the Microbiome with Polyphenols, Probiotics, and Postbiotics. In: Haslberger AG, editor. Advances in Precision Nutrition, Personalization and Healthy Aging. Cham, Switzerland: Springer Nature; 2022; p. 145-78.
66. Mathers JC. Paving the way to better population health through personalised nutrition. EFSA J. 2019 Jul 8;17(1):170713.
67. Drabsch T, Holzapfel C. A Scientific Perspective of Personalised Gene-Based Dietary Recommendations for Weight Management. Nutrients. 2019 Mar 14;11(3):617.
68. Celis-Morales C, Livingstone KM, Marsaux CF, Macready AL, Fallaize R, O'Donovan CB, et al. Effect of personalized nutrition on health-related behaviour change: evidence from the Food4Me European randomized controlled trial. Int J Epidemiol. 2017 Apr 1;46(2):578-588.

Dijetarne intervencije kod gojaznosti: pregledni rad

Olina Dudašova Petrovičova[1*], Ivana Đuričić[1], Nevena Ivanović[1], Nevena Dabetić[1], Margarita Dodevska[2], Tijana Ilić[1]

[1]Univerzitet u Beogradu – Farmaceutski fakultet, Katedra za bromatologiju, Vojvode Stepe 450, 11221, Beograd, Srbija

[2]Institut za javno zdravlje Srbije „Dr Milan Jovanović Batut", Centar za Higijenu i humanu ekologiju, 11000 Beograd, Srbija

*Autor za korespondenciju: Olina Dudašova Petrovičova, e-mail: olina.dudasova@gmail.com

Kratak sadržaj

Prema podacima Svetske zdravstvene organizacije, 2022. godine je oko 890 miliona odraslih i 160 miliona dece i adolescenata širom sveta bilo gojazno, što daje povoda za značajnu zabrinutost za javno zdravlje. Gojaznost nastaje usled prekomernog unosa i smanjene potrošnje kalorija tokom dužeg vremenskog perioda, a manifestuje se uvećanjem masnog tkiva, telesne težine i pojavom metaboličkih poremećaja. Tretman gojaznosti podrazumeva promene u načinu ishrane i stilu života. Dijete sa ograničenim unosom kalorija i zamene za obroke se često preporučuju za postizanje gubitka telesne težine i smanjenje ukupnog unosa energije. Dijete obuhvataju ishranu sa niskim sadržajem ugljenih hidrata, dijetu sa niskim sadržajem masti ili visokoproteinsku dijetu. Pored toga, poslednjih godina se sve više ispituje uticaj mediteranske ishrane i dijetetskih vlakana u regulaciji telesne težine. Dijetetski proizvodi namenjeni regulaciji telesne težine dizajnirani su da zamene obroke i nude opcije za pojedince koji žele da redukuju telesnu masu. Pojavljuju se personalizovani pristupi ishrani koji se fokusiraju na individualne potrebe, genetske faktore i sastav crevne mikrobiote kako bi se optimizovali zdravstveni ishodi. Iako personalizovana ishrana ima sve veću primenu u nutritivnoj terapiji, potrebna su dalja istraživanja kako bi se bolje razumela njena efikasnost kod pacijenata sa gojaznošću.

Ključne reči: gojaznost, dijetarne intervencije, personalizovana ishrana