REVIEW PAPER

JMS Journal of Medical Science

The role of the dietary patterns in the cardiovascular disease risk prevention

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DOI: https://doi.org/10.20883/medical.e704

Keywords: cardiovascular risk, Mediterranean diet, ketogenic diet, vegetarian diet, DASH diet

Published: 2022-09-20

How to Cite: Pelczyńska M, Burak W, Królak S, Geppert A, Lipczyński M, Grzybołowska J, Kociubiński P. The role of the dietary patterns in the cardiovascular disease risk prevention. Journal of Medical Science. 2022;91(3):e704. doi:10.20883/medical.e704

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ABSTRACT

Cardiovascular diseases (CVD) are a part of a wide group of diseases, which became main threat to the life and health of the population in highly developed countries. To prevent and treat CVD, in addition to implementation of pharmacological methods, there are a number of lifestyle components, including eating habits, that significantly influence the development of these diseases. The dietary patterns strongly correlate with the risk of cardiovascular disease. Modifications of the dietary habits allow to control many parameters such as: body weight, cholesterol/triglyceride levels or blood pressure. Alternative diets are frequently used to reduce the risk of developing a CVD. The main recommended dietary patterns includes Mediterranean diet (MD), the DASH diet (Dietary Approach to Stop Hypertension) and mild variants of vegetarianism. The more controversial nutritional styles includes the ketogenic or vegan diets. Due to various assumptions as well as the mechanisms of action of each diets, an attempt of its evaluation have been made. The aim of our study is to review and analyze the available data on the impact of various nutrition models regarding to cardiovascular diseases risk prevention.

Introduction

Cardiovascular diseases (CVD) are a part of a wide group of diseases, which became main threat to the life and health of the population in highly developed countries. According to World Health Organization (WHO), in 2019 almost 17.9 million people have died from cardiovascular diseases, accounting for 32% of all deaths in the world, with the number still growing annually [1]. To prevent and treat CVD, in addition to implementation of pharmacological methods, there are a number of lifestyle components that significantly influence the development of these diseases [2]. Lifestyle is a widely understood concept that describes the patterns of human behavior, which depends on factors such as the economic situation or socio-cultural norms [3]. Among the most impactful aspects, activities as smoking, alcohol consumption, physical activity and diet can be mentioned. The latter one is a specific model of nutrition depending on elements such as location, economic situation, socio-cultural influences or the level of education. The dietary patterns strongly correlate with the risk of cardiovascular diseases. Modifications of the dietary habits allow to control many parameters such as: body weight, cholesterol/triglyceride level or blood pressure (BP). The high content of saturated fatty acids, cholesterol or the total amount of calories may predispose to the development of cardiovascular diseases [4, 5]. Alternative diets are frequently used to reduce the risk of developing a CVD. The main recommended dietary patterns include Mediterranean diet (MD), the DASH diet (Dietary Approach to Stop Hypertension) and mild variants of vegetarian diets [6-8]. The more controversial nutritional styles include the ketogenic or vegan diets [9, 10]. Due to various assumptions as well as the mechanisms of action of each of diets, an attempt of its evaluation have been made

The aim of our study is to review and analyze the available data on the impact of various nutrition models regarding to cardiovascular diseases risk prevention.

The Mediterranean diet

The Mediterranean diet is currently the most proper diet recommended by WHO towards CVD risk improvement [11]. It is known from the 50s and 60s of the 20th century as a dietary pattern derived from Mediterranean Basin [12]. The region is bordered by 18 countries that are diverse in terms of economic and healthcare status, lifestyle, and dietary patterns. Duo to the fact that it is impossible to define a solitary version of MD, two scores methods that helps classify dietary patterns individually were invented. Mediterranean Adequacy Index (MAI) assesses amount of typical Mediterranean foods as fresh vegetables and fruits, legumes, wholegrains, seafood, olive oil and red wine and untypical foods as red meat, eggs, dairy products, and sweets which consumption should be limited. The second one is Mediterranean Diet Score (MDS) which determinates typical MD products intake as positive (1 point) and untypical foods intake as negative (0 points). The score totals from 0 to 9, and its higher result stand for better compliance to a traditional MD [13]. One of the biggest studies of health-promoting impact of MD is HALE project (Healthy Aging: a Longitudinal Study in Europe) that used data of individual long-term surveys as SENECA (Survey in Europe on Nutrition and Elderly: a Concerned Action) and FINE (Finland, Italy, the Netherlands, Elderly). It reports that MD (hazard ratio (HR): 0.77; 95% confidence interval (CI): 0.68-0.88) together with physical activity (HR: 0.63; 95% CI: 0.55-0.72), moderate alcohol usage (HR: 0.78; 95% CI: 0.67-0.91) and non-smoking (HR: 0.65; 95% CI: 0.57-0.75) were associated with a lower risk of all-cause mortality [14]. Over time the MD has been endeared by other European regions as a proper way of nutrition in many clinical conditions with particular references to CVD. The main preventive action of MD include high ratio of monounsaturated fatty acids to saturated fatty acids, high content of polyphenols and antioxidants, as well as reduced calorie intake [12, 15].

The study conducted by Estruch R et al. reports that MD with high amount of extra virgin olive oil or nuts followed for an average period of time by 4.8 years reduces the risk of CVD episodes as stroke, myocardial infraction or coronary heart disease [16]. The high consumption of monounsaturated fats (MUFA), mostly from extra virgin olive oil, combined with low intake of saturated fats (SFA) cause the decrease in plasma low-density lipoprotein (LDL) level. Keeping LDL on possibly the lowest level may be as effective as statin's therapy which is used to treat progression of atherosclerosis that consequently leads to major CVD [17]. High MUFA/SFA ratio also has significant influence on decreasing CVD mortality and overall mortality at general as reported by a prospective investigation in Greece of Trichopoulou et al. [18]. Additionally, highly consume nuts and wholegrains are rich in omega-6 and omega-3 fatty acids and plant sterols which are involved in LDL lowering mechanism [14].

Another important function of the MD is its anti-oxidative and anti-inflammatory properties, mostly thanks to high content of polyphenols, vitamin C, vitamin E and β-carotene contained in vegetables and fresh fruits [14]. A cohort study of the MOLI-SANI reports that high-antioxidant enriched MD decreases glucose, lipids, CRP (C-reactive protein) and blood pressure levels what in turn reduces systemic inflammation damages and oxidative stress [19]. Those are highly corelated to endothelial dysfunction that initiate the atherosclerosis pathogenesis [20]. The main mechanism involved in the prevention of this disease include the inhibition of pro-inflammatory biomarkers production [7, 21]. The PREDIMED study observations indicate that one year of compliance with MD diet decrease VCAM-1 (vascular cell adhesion molecule-1), ICAM-1 (intercellular ahesionmolecule-1), IL-6 (interleukin-6), MCP-1 (monocyte chemotactic protein-1), TNF-α (tumor necrosis factor- α) compared with initial readings [22]. Simultaneously, transcription factor as NF-κB (nuclear factor kappa B) and signal transduction cascades are increasingly activated what leads to high production of inflammatory cytokines and to decrease the synthesis of NO (nitric oxide). Vasoactive features of NO have direct influence on cardiovascular system through LDL and triglycerides lowering effect, blood pressure improvement, decreasing of platelets aggregation (**Figure 1**) [23].

As mentioned above, the anti-oxidative and anti-inflammatory capacity of MD result from high content of phenolic compounds. They are present in the main key foods of this dietary pattern as extra-virgin olive oil, nuts, legumes, vegetables, fruits, and whole-grain cereals [24]. Additional sources of polyphenols in MD is light-to-moderate red wine consumption. The main vasoactive components of red wine are flavonoids. Its effect comprises LDL and triglyceride levels reduction, systolic and diastolic blood pressure improvement, endothelial vasodilatory stimulation, decrease of platelet aggregation and lowering the proinflammatory and oxidant mediators produc-

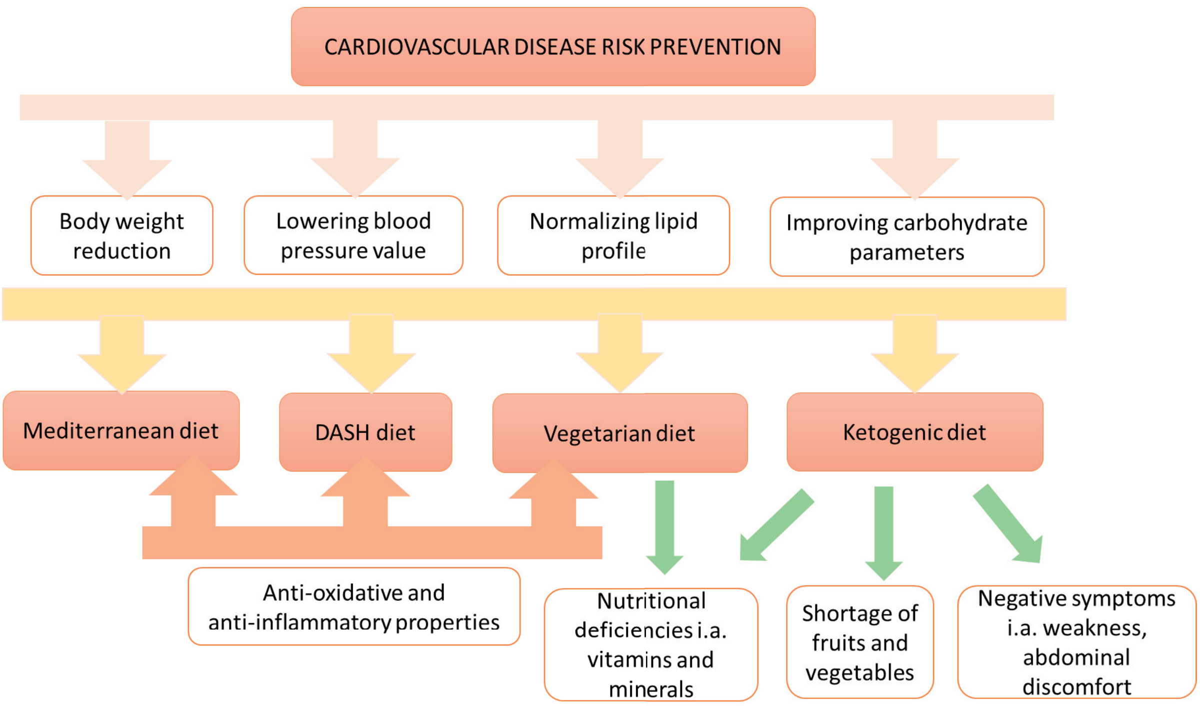

Figure 1. The effect of different dietary patterns on cardiovascular diseases risk prevention

tion [7]. Moreover, ethanol increases high-density lipoprotein (HDL) levels, promotes fibrinolysis and reduces systemic inflammation [21].

The important part of MD is high consumption of fishes and seafood. Those kind of food is rich in omega-3 fatty acids and provide high content of proteins, vitamin D, B vitamins, calcium, selenium as well as other nutrients (i.a. L-arginine) [25]. Data form clinical research have shown that fish consumption lead to reduce the potential risk of CVD including myocardial infarction [26], hypertension [27] or stroke [28]. The mechanism of protective fishes consumption involved their anti-inflammatory, anti-arrhythmia and anti-hypertension properties due to omega-3 fatty acids action. Moreover, unsaturated omega-3 fatty acids have triglyceride lowering as well as vasodilator effects [29]. A meta-analysis form 2020 indicated that high fish intake was correlated with a lower coronary heart disease incidence – CHD [relative risk – RR: 0.91, 95% CI: 0.84, 0.97]. What is more, the dose-response analysis demonstrated that the incidence and mortality of CHD were reduced by 4% together with a 20 g per day increment in fishes consumption [30]. In contrast not all studies show association between fish intake and CVD risk prevention [31], thus more analysis in this area are needed.

It is indicated that MD may be a useful dietary pattern in weight gain prevention and weight loss (**Figure 1**). Meta-analysis of randomized controlled trials showed that MD is an effective tool to reduce an excessive body weight, especially when it is energy-restricted, combined with physical activity, and lasts more than 6 months [32]. In other systemic review it has been observed that MD results in similar weight loss and CVD risk reduction as other comparator diets (low-fat diet, low-carbohydrate diet, the American Diabetes Association diet) in overweight or obese individuals [33]. Weight reduction is an important factor affecting the CVD risks. In one study Authors showed that 5-10% reduction of the initial body weight corelates with the decries in triglycerides, total cholesterol, LDL cholesterol and fasting glucose level. Losing more than > 10% of body weight produced improvements in cardiovascular risk factor in general [34].

The disadvantages of MD are difficult to define. There are singular reports on low or zero effect of MD on CVD risk improvement. Michalsen et al. [35] found no influence of MD on inflammation markers and metabolic risk in patients with artery disease. The MD is treated more like dietary pattern than strict regimen. Relevantly low-calorie intake and well-balanced structure make this diet easier to adherence. Nevertheless, the caloric value of the diet should be well-balanced according to the Body Mass Index (BMI). For example, the olive oil (regardless of its advantages) contains about 120 calories per spoon. Its uncontrolled, overload consumption may lead to body weight gain with adipose tissue accumulation in abdominal area. That condition may predispose to chronic low-grade inflammation, oxidative stress, and worsen of metabolic health at general. Thus, the benefits resulting from preventive properties of MD will be suppressed [36] and considerable as disadvantage. Worth mentioning is a fact that advantages of wine consumption are also still considered in terms of damaging influence of ethanol, which overconsumption in turn may contribute to the atherosclerosis [37].

In conclusion, dietary pattern has crucial influence on shape of cardiovascular condition and health as a whole. The MD bases on both quality and quintinite components. It has comprehensive impact on cardiovascular health mostly focused on anti-atherosclerosis prevention, which is departure point of major CVD as stroke, myocardial infraction or coronary heart disease. The individual form and flexibility of the diet makes it the most recommended due to particularly no contraindications and it approaches the gold standard for cardiovascular health.

DASH diet

DASH diet is considered as an effective nutritional change designed to reduce high blood pressure and the level of low density lipoprotein cholesterol [38]. Hemodynamic (hypertension) and metabolic (hyperlipidemia) stressors are considered as important risk factors in development of CVD [39]. The variety of studies confirms diet's positive effect on reduction of CVD risk factors (**Figure 1**) [38, 39].

DASH diet is similar to Mediterranean dietary pattern. It is based on high intake of fruits, vegetables as well as dairy products with low fats content. The DASH diet is rich in wholegrain products, fishes, nuts and poultry. During following the diet the reduction of total and saturated fats, sweets, sugary drinks and meat is urged [40]. Thus, it supplies the food rich in calcium, potassium, magnesium, roughage and vegetable proteins [39]. Even though DASH diet may be considered as similar to Mediterranean one, according to various of studies, DASH diet has a more significant impact on BP. However, the analyzed studies confirms, that the adherence of both of these diets has a positive impact on the reduction of the cardiovascular disease risk factors [6].

While looking at DASH diet's mechanism, it exhibits protective effects for human various systems and its physiological functions. The mechanisms include the modification of antioxidant capacity, function of liver, inflammatory response, coagulation, activation of sympathetic system, control of insulin and glucagon, endothelial function and natriuresis [41].

According to research data, it may be considered, that several nutrients including sodium and potassium, are critical in high BP reduction during DASH diet undergo. Sodium intake affect negatively on the cardiovascular system-due to increase BP. Excess of sodium intake may be also correlated with CVD in mechanism not only related with hypertension [42]. Excess of sodium is corelated with intense albumin excretion, oxidative stress or increase of glomerular hydrostatic pressure [42].

The hypertension related to excessive sodium intake is connected with developed water retention that leads to increased blood flow in arteries. The increased BP in this case may lead to higher water and salt excretion [43]. This may lead to remodeling of arterial vessels, it may be corelated with changes in vascular resistances [44]. According to AHA (American Heart Association) it is highly recommended to reduce daily sodium intake to < 1500 mg/day in order to reduce all of the risk factors correlated with the development of CVD (both related and not-related to hypertension) [45]. The diseases have direct connection with excess of sodium intake include structural and functional impairment of the heart, kidneys and big vessels [42].

Independently of medicines intended to preventing hypertension, the diet should be an important lifestyle factor correlated with the reduction of the cardiovascular risk [46]. In the creating of the DASH diet sources of daily energy requirements are significant. The diet should consist of 15-20% from proteins, 25-30% from lipids and 55-60% from carbohydrates [47]. Clinical studies showed that the significant changes in systolic (SBP) and diastolic blood pressure (DBP) were observable in patients with hypertension following the DASH diet. The systematic review and meta-analysis conducted by Siervo M. et al., showed the significant decrease of SBP value (by 5.20 mmHg; $p < 0.001$) as a result of DASH diet undergo. Moreover, the reduction in the DBP value by 2.60 mmHg ($p < 0.001$) was also observed [39]. Lin P.H. et al. in their study also proved noticeable changes between control group and population following the DASH diet. The SBP values had been reduced approximately by 10.65 mmHg (±12.89 mmHg; $p = 0.023$) in the first week of the study. The effect of the SBP decrease were also noticeable on the second week of the experiment, where SBP values were lowered by 9.60 mmHg (±11.23 mmHg; $p = 0.039$) [48]. DBP also had been reduced in both cases by 5.95 mmHg (±8.01 mmHg; $p = 0.069$) in the first week of the study and by 8.60 mmHg (±9.13 mmHg; $p = 0.011$) after two weeks. The ions concentration also are crucial in reduction of BP in DASH diet. In simple linear univariate regression, the changed in urinary Na^+, K^+ and Na^+/K^+ proved the correlation with the reduction of SBP and DBP [48].

The diversity of researched people, in the study mentioned above conducted by Siervo M. et al. proved that BP reduction is most significant in African American population. More significant BP reductions were noticed in participants with the higher initial BP values and higher BMI [39].

The majority of the studies had proved that the aim of BP reduction is reached while following the dietary pattern. However, according to the study held by Appel LJ. et al. (PREMIER clinical trial), DASH diet's impact on blood pressure reduction was not as significant as it was assumed. According to the results – the decrease of SBP while following the DASH diet and established recommendations was only approximately 0.60 mmHg more significant than in participants with implemented established recommendations without diet [49].

It is worth mentioning that DASH diet's influence not only BP values but also modifies cholesterol fractions concentrations in the blood (**Figure 1**). Hypercholesterolemia makes up the crucial risk of the development of variety of CVD including arteriosclerosis that may result in myocardial infarction [50]. The studies conducted by Mensink R.P. et al. [51] and Clarke R. et al. [52] showed that HDL level had been increased in case of DASH diet. Contrary, some researches submitted that DASH diet resulted in lowering the fraction HDL by 3.7 mg/dl, what may be considered an issue in connection with cardiovascular risk [53]. Such an effect may result from low dietary fat intake, since the reduced-fat dietary patterns lead to decrease of HDL level [53].

DASH diet makes also an impact on the other aspects directly correlated with reduction of cardiovascular risk. One research showed a considerable improvement of insulin sensitivity as well as the reduction of oxidative stress on the DASH diet (**Figure 1**) [54]. The factors which's values significantly change while following DASH diet included fasting glucose concentration and HOMA-IR level (Homeostatic Model Assessment – Insulin Resistance). Those are major cardiovascular risk factors that occur in abnormal glucose tolerance or type 2 diabetes which often lead to micro- and macroangiopathy. Both of them may be reduced by following the DASH diet's rules [54]. The recent studies proved also diet's impact on minimalizing cardiovascular incidence as stroke [55]. These results were confirmed in a systematic review and meta-analysis on observational prospective studies performed by Salehi-Abargouei A. et al. [56].

Another aspect worth mentioning is the influence of DASH diet on body weight and composition. Soltani et al. showed that this dietary pattern is effective in weight management (especially weight reduction) in overweight and obese subjects. The analysis of 13 articles pointed out that adults on DASH diet lost more weight (weighted mean difference – WMD: -1.42 kg, 95CI: -2.03, -0.82), BMI (WMD: – -0.42 kg/m^2, 95%CI: -0.64, -0.20) and waist circumference (WMD: – -1.05 cm, 95%CI: -1.61, -0.49) when compared with other low-energy diets [57]. Also other randomized controlled trial demonstrated that following the DASH diet for 8 weeks among patients with non-alcoholic fatty liver disease (NAFLD) had beneficial effects on not only to body weight and BMI, but other metabolic parameters (triglycerides, markers of insulin metabolism and inflammatory response) correlated with CVD as well [58].

To conclude it may be observable that DASH diet had caused an decrease of SBP and DBP, however some researches performed its insignificant impact in this specific case. According to analyzed studies, DASH diet is correlated with the decrease of total cholesterol and LDL cholesterol fraction, it may be surely interpreted as a valuable aspect in decrease of cardiovascular risk. Many implications including an impact on glucose, HDL and triacyclglycerols level are still missing, because of the ambiguous research results [59]. The DASH diet had been created in order to prevent the hypertension and persistent metabolic diseases. The reduction of those risk factors may be connected with lowering possible complications of CVD. Overall, the DASH diet then is highly recommended for adults mainly with pre-hypertension or stage 1 hypertension, but also for the population in general.

Ketogenic diet

Ketogenic diet (KD) is a dietary pattern characterized by low intake of carbohydrates (< 50 g/day) [60], increased consumption of fat and an adequate amount of protein. Although this diet is mainly used for treating pediatric patients suffering from epilepsy [61], it has been gaining popularity among people trying to reduce an excessive body weight. Due to poor consumption of carbohydrates organism has to adapt and find a new energy source for the peripheral tissues and the brain, which leads to break down the fatty acids by the liver and produce ketone bodies (KB – acetoacetate, beta-hydroxybutyrate and well known acetone) [62] as an alternative sources of energy [61]. These situation cannot be compared to pathophysiological ketosis which occurs in type 1 diabetes. The latter cause significantly increase in concentration of ketone bodies results in blood pH decreasing and a life-threatening situation. On the other hand ketonemia from the diet does not increase ketone bodies to dangerous levels because of usage them by central nervous system (**Table 1**) [61].

Ketogenesis occurs in liver's cells mitochondria matrix [63]. Ketone are transported via blood to tissues such as central nervous system and

Table 1. Blood levels during a normal diet, ketogenic diet and diabetic ketoacidosis

Blood Levels	Normal Diet	Ketogenic Diet	Diabetic Ketoacidosis
Glucose (mg/dL)	80–120	65–80	>300
Insulin (μU/L)	6–23	6.6–9.4	≈0
[1]KB (mmol/L)	0.1	7/8	>25
pH	7.4	7.4	<7.3

[1]KB – ketone bodies.
Based on: [61].

skeletal muscles and metabolized by them. Then KB are converted into acetoacetyl-CoA, which afterwards is transformed into 2 acetyl-CoA, which are used in Krebs cycle for energetical purposes of the cells [61].

Hypertension represents one of the main components of the metabolic syndrome. It has been observed that ketogenic diet helps to reduce an excessive body weight which ensure the control of blood pressure rate (**Figure 1**) [64]. A study conducted on 377 patients put on VLCKD (very low calories ketogenic diet) diet, showed an improvement in SBP (−10.5 ± 6.4 mmHg, $p < 0.001$), as well as in DBP (−2.2 ± 3.1 mmHg, $p < 0.001$). Although, the effect has only been observed only up to 3 months of the studies with no further changes after 1 year of observation [65]. On the other hand, one meta-analysis found a significant difference in SBP between diet groups in favor of low-CHO (low -carbohydrate) diets (−2.74 mm Hg; 95% CI: −5.27, −0.20, p =.03), but no difference in DBP [66]. Moreover, a metanalysis (13 studies) conducted by Beuno NB. et al. showed difference in DBP (-1.43 mmHg; 95% CI: -2.49, -0.37, 1298 patients) but not in SBP in patients put on VLCKD [67].

Ketogenic diet may also influence the carbohydrate metabolism (**Figure 1**). The study performed on 12 overweight patients (BMI ≥ 25 kg/m^2) with type 2 diabetes, that were put on very low calories ketogenic diet for 32 weeks, has proven a significant reduction in hemoglobin A1c (HbA1c) serum levels (–0.8%, 95% CI: –1.1%, –0.6%) compared to participants from the control group. Moreover, participants from intervention group lost more weight and lowered their triglyceride levels [68]. Decreased blood glucose levels as a result of KD were confirmed in another studies [69, 70]. What is more, VLCKD has been proven to increase tissues' insulin sensitivity [70].

Dyslipidemia is another risk factor for the development of CVD. A results from clinical research have shown significant positive changes in lipids profiles among individuals following ketogenic diet (**Figure 1**). It included the reduction of: concentration of triglycerides and total cholesterol levels as well as an increase in HDL concentration [50]. In a meta-analysis of randomized controlled trials, occurring type 2 diabetes patients, improved lipid profiles in terms of lower triglyceride (standardized mean difference – SMD: -0.45; p = 0.01) and greater high-density lipoprotein (SMD: 0.31; p = 0.005) have been evaluated [71]. On the other hand, not all studies conformed this results. In other meta-analysis no difference was found in total cholesterol, HDL, and LDL levels after 3, 6, and 12 months of treatment ($p > 0.05$) in type 2 diabetes patients put on VLCKD [72].

It has been proven, that ketone bodies have a suppressant effect on appetite, which predispose to body weight reduction [73]. It seems that the ketogenic diet can also induce the reduction of adipose tissue without loss of lean body mass [74]. Studies on obese individuals showed that during exercise an increase efficiency of adipose tissue oxidation is present. This effect may be caused by higher free fatty acids level, which enhance transport across the mitochondrial membrane and therefore more substrate for fat oxidation [75]. Thus, the ketogenic diet is also an effective way to reduce body weight. Goss et al. demonstrated that a very low carbohydrate diet may be beneficial for older obese adults by depleting the amount of adipose tissue and improving the metabolic health (insulin sensitivity and the lipid profile) [76]. Also in a meta-analysis mentioned above, besides improvements the metabolic dysfunction and minimalizing the risk of CVD in obese subject, ketogenic diets led also to substantial weight reduction (SMD, -0.46; p = 0.04) [71].

On the other hand some publication shows the negative effects of a ketogenic diet [77]. This diet is poor in most of fruits and vegetables, which are an important source of vitamins and minerals. For this reason some patients on the ketogenic diet may suffer from hypovitaminosis (thiamin – B1, folate, pyridoxine – vitamin B6, vitamin A, vitamin K), minerals deficiency (calcium, magnesium, iron, and potassium), dyselectrolytemia or dehydration [78, 79]. What is more patients on low calories ketogenic diet are predispose to suffer from bone mass and structure impairment [80]. Shortage of fruits and vegetables, which are main sources of protective substances such as antioxidants and polyphenols can induce increased exposure to free radicals. This imbalance might be harmful especially for patients with type 2 diabetes, where free radicals play an important role in the development of its metabolic complications [81]. The already mentioned dehydration causes decrease in thirst due to presence of ketones as well as low supply of fiber, due to low fruit and vegetables contents in the diet, what may induce constipations in some patients [82]. Moreover, low water supply combined with excessive production and reduced excretion of uric acid can cause higher risk of hyperuricemia and formation of urate stone in individuals following ketogenic diet. Thus, it is important to control level of uric acid in these patients [83]. One of the most common negative symptoms associated with ketogenic, are abdominal discomfort, nausea or vomiting. These symptoms may intensify after consuming larger amounts of the fatty acids [84]. Other adverse effects associated with the ketogenic diet are constipation and headache (**Figure 1**) [78].

To sum up, ketogenic diet has increased in popularity among many people. It has been proved to have positive influence over the human body in particular cardiovascular risks, such as: blood pressure, glucose serum level, obesity and dyslipidemia. Although, unbalanced KD may cause some side effects. Moreover, there are no clearly results on only negative or positive influence of KD on human organism, thus more randomized controlled trials in this area are needed.

Vegetarian diet

Due to significant raise in popularity, vegetarian diet is considered as an important alternative dietary pattern. There are several reasons, including environmental, ethical and medical factors, for whom the Western civilizations are deciding to withdraw animal products from their daily nutrition [85]. This type of diet is also highly promoted as healthy and therefore it should be examined how it correlates with cardiovascular risk and its factors [86].

There are several variations of so-called plant-based diets (PBDs). Each type is characterized by the range of excluded animal products. These variations are summarized in **Table 2**,

Table 2. The types of vegetarian diet

Type of diet	Summary of definitions
Flexitarian (semi-vegetarian)/meat reductionism/reducetarian	Occasional inclusion (less than once per week) of flesh foodstuff (meat, poultry, and fish) and permits eating all other animal products (e.g., eggs, milk, honey)
General vegetarian diets	Whenever not specified, a vegetarian diet is often an ovo-lacto-vegetarian diet
Pescetarian (pesco-vegetarian)	Includes seafood/fish, but not flesh of other animals (meat, poultry), and permits eating all other animal products (e.g., eggs, milk, h oney). This diet is sometimes included in the semi-vegetarian group
Pollo-vegetarian	Poultry is the only animal flesh consumed, as well as dairy and egg products. This diet is sometimes included in the semi-vegetarian group
Ovo-lacto-vegetarian	Excludes all types of flesh foodstuffs (meat, poultry, fish), but permits eating all other animal products (e.g., eggs, milk, honey)
Lacto-vegetarian	Excludes flesh foodstuffs and eggs but allows dairy products, honey
Ovo-vegetarian	Excludes consumption of all animal products with the exception of eggs
Vegan	Diet which excludes all animal products (both as ingredients and processing aids, the latter being an important aspect); an exception is human mother's breast milk, given voluntarily; veganism can also imply excluding all items of animal origin (e.g., made from wool, silk, leather materials) Other subcategories of a vegan diet are: – Vitarian (raw vegan): permits consumption of organic, raw, and fresh foods only; excludes coffee and tea – Fruitarian: excludes flesh foodstuffs, animal products, and vegetables, cereals permitted are only fruit, nuts, seeds, which can be gathered without damaging the plant – Sproutarian: eating foods in the form of sprouted plant seedlings, such as grains, vegetables, fruits

Based on: [87].

based on division that is most often used in research [87].

In 1999 Key et al. analyzed 5 prospective studies with 76 172 participants on vegetarian diet and established a 24% lower mortality from ischemic heart disease (IHD) [88]. However there was no association between this particular dietary pattern and any other significant cause of death. In 2012 Huang et al. confirmed these conclusions in their meta-analysis. Seven studies were examined with 124 706 participants overall and it was found that vegetarians had 29% lower chance of death from IHD [89]. Another evidence comes from EPIC-Oxford cohort study where risk or fatal cases of IHD were taken into consideration [90]. The study showed a 32% lower chance of suffering from IHD when following a vegetarian diet. What is important, taking into account other risk factors as sex, age, BMI and smoking, the diet had an important influence on CVD occurrence [90]. Potential mechanisms responsible for these results will be discussed below.

Crowe et al. stated that one of the key elements lowering the risk of IHD in the vegetarian group is its effect on non-HDL cholesterol [90]. Dyslipidemia is a well-studied risk factor for cardiovascular diseases [91]. Zhang et al. studied the effects of vegetarian diet on BMI and lipid profile in Chinese vegetarians and concluded that this dietary pattern corelates with favorable lipid profile and lower BMI [92]. The occurrence of BMI lowering during vegetarian diet is emphasized in several other studies [93-95]. A meta-analysis of randomized controlled trials evaluated a significant benefits on weight reduction compared to non-vegetarian diets. Subjects from vegetarian groups reduced more weight comparing to the control i.a. non-vegetarian diet groups (WMD: -2.02 kg; 95 % CI: -2.80, -1.23). Participants consuming a vegan diet were characterized by significant weight reduction (WMD: -2.52 kg; 95 % CI: -3.02, -1.98) and individuals consuming lacto-ovo-vegetarian diets showed lower effect due to weight loss (WMD: -1.48 kg; 95 % CI: -3.43, 0.47). What is more, vegetarian diets with energy restriction revealed even a greater weight reduction (WMD: -2.21 kg; 95 % CI: -3.31, -1.12) [96]. Therefore, due to the fact that weight reduction has an positive effect on blood lipids and lipoproteins [97], vegetarian diet may help to reduce both risk factors.

There is an evidence that plant-based dietary pattern has blood pressure lowering properties (**Figure 1**). Lee et al. in their meta-analysis noted that vegetarians have lower the SBP (WMD: −2.66 mmHg; 95% CI: −3.76, −1.55, $p < 0.001$) and DBP (WMD: −1.69 mmHg; 95% CI: −2.97, −0.41, $p < 0.001$) compared to omnivores [98]. Similar outcomes were found by Yokoyama et al. in 2002 [99]. It is believed that those results emerge from the diet's effectiveness in weight reduction as well as high potassium, magnesium and fiber content. Ernst et al. also proved that vegetarians tend to have lower blood viscosity, which possibly have impact on their BP [100].

As was already mentioned, PBDs are characterized by large levels of dietary fiber [101], especially this classified as water-soluble. It is believed that water-soluble fiber enhance satiety, therefore may be crucial in maintenance of body weight [102]. Kromhout et al. in the Seven Countries Study pointed out that dietary fiber is crucial in obesity and cardiovascular diseases prevention [103].

There are few mechanisms suggested the preventive properties of vegetarian diet in the context of CVD. Besides a clear impact on lipid profile, high intake of antioxidants is also signalized as a meaningful factor that prevents from atherosclerosis (**Figure 1**) [104]. Studies focuses mainly on ascorbate and alpha-tocopherol. Szeto et al. made a small cross-sectional study on 30 long-term vegetarians which supported their hypothesis that plasma vitamin C may be used as a general health marker due to its inverse relation with high sensitive CRP [105]. This thesis is consistent with other studies presenting the relation between ascorbate levels and cardiovascular health [106]. In addition, not only PBDs assure vital nutrients such as dietary fiber or antioxidants due to high vegetable intake, but also remove meat consumption (particularly red meat) with high content of nucleic acids, which may result in higher uric acid levels among omnivores. Urate is considered as an independent mortality predictor of mortality in patients with coronary artery disease (CAD) [107]. In 2013 Koeth et al. examined the metabolism of L-carnitine which leads to production of trimethylamine-N-oxide (TMAO) [108]. TMAO is proatherogenic and therefore its accumulation elevates cardiovascular risk. Indeed, the researchers found that dietary levels of L-carnitine was associated with cardiovascular event risk (p = 0.04). The same study claims that vegetarians and vegans have significantly lower L-carnitine levels as well as plasma TMAO concentration. Adding up to the benefits of meat removal, Micha et al. established that processed meats are associated with coronary heart disease occurrence [109], however it is stated that red meat has no such influence. To our knowledge, it seems that further research is needed.

In 1985 Snowdon et al. brought up a hypothesis that vegetarian diet reduces risk of suffering from type 2 diabetes [110]. It is proven that the pattern helps to improve insulin sensitivity [111] and also lowers HbA1c levels (p = 0.046) which is corelated to high vegetable intake [112]. In addition, Villegas et al. concluded that vegetarians are significantly more protected against T2D incidence [113]. To add up, research provided data suggesting that low-fat vegan diet may have better results in glycemic control of patients already suffering from diabetes [114]. The pattern was compared to a diet suggested by American Diabetes Association [115] with results over 22 week clinical trial [114], which have been shown in the **Table 3**.

Data from clinical studies often evaluates the effect of plant-based diets on risk of CVD as general without showing the exact dietary pattern (vegan or vegetarian). There is no doubt, that the elimination of animal products is beneficial in the context of metabolic health. A meta-analysis and systematic review of prospect cohort studies indicated that an overall plant-based diet was significantly associated with a lower risk of CVD mortality (pooled HR: 0.92, 95% CI: 0.86, 0.99, p = 0.0193) and risk of CVD incidence (pooled HR: 0.90, 95% CI: 0.82, 0.98, p = 0.0173) [116]. Other prospective study from UK Biobank compared vegetarians, fish, poultry, and meat-eaters in the context of CVD incidence. It has been showed that fish-eaters rather than meat or poultry had lower risk of adverse cardiovascular outcomes. Vegetarians had only lower risk of CVD incidence [117]. It seems that plant-based diet minimalize the risk of CVD mainly due to consumption of low calorie and fat food as well as modification of lifestyle in general. Nevertheless, vegetarianism is characterized by a lower risk of nutritional deficiencies (i.a. proteins, vitamins and minerals), thus often is recommended as alternative dietary pattern in different population groups [8].

The main concern about PBDs, especially vegan diet, are possible deficiencies (**Figure 1**). According to Craig, it is important to be aware of an effective incorporation of calcium, zinc, iron, long chain omega-3 acids, vitamin D and vitamin B12 [118], the latter being most often discussed. A review performed by Pawlak et al. in 2013 strongly stated that vegetarians are at significant risk of developing B12 deficiency [119]. Two years later Pawlak suggested that such abnormal levels of the vitamin may lead to hyperhomocyteinemia, increasing CVD risk [120]. In addition, small cross-sectional study performed by Weikert et al. in 2020, presented an additional recommendations that vegetarians should care more about iodine intake [121]. What seems crucial in case of previous discussion, this trial's results did not signalize differences in B12 levels between vegans, vegetarians and omnivores which probably was an effect of supplementation, therefore it underlines the importance of additional intake of this vitamin.

In conclusion, plant-based dietary patterns may reduce cardiovascular risk in several different ways. While regular supplementation is needed, it seems that vegetarian or vegan diet should be considered in clinical approach, particularly when patients may find them attractive not only

Table 3. Elected results from randomized controlled trial (n = 99, 22 weeks) showing the benefits from low-fat vegan diet vs a diet following the American Diabetes Association (ADA) guidelines

Elected results/diet	Low-fat vegan diet ([2]n = 49)	Diet followed by [1]ADA recommendation (n = 50)
% of participants that reduced diabetes medications	43%	26%
[3]HbA1C decrease (P = 0,089)	0,96 percentage points	0,56 percentage points
Body weight decrease(P < 0,001)	6,5 kg	3,1 kg

[1]ADA – American Diabetes Association; [2]n – number of participants; [3]HbA1C – hemoglobin A1c.
Based on: [114].

because of health benefits. Additionally, vegan diet tends to have great potential as a dietary pattern for people suffering from type 2 diabetes and further research in this topic should be made.

Conclusion

Lifestyle changes correlate with the prevalence of CVD. Studies indicate that well balanced nutrition modify the risk of chronic diseases occurrence. Moreover, diet is one of the most important factors which may have the influence on the cardiovascular risk and it has been proven that diet components play an important role in CVD prevention. A number of the most commonly used dietary patterns including Mediterranean, DASH, vegan and ketogenic were analyzed in the context of the development of cardiovascular risk. As illustrated in this review, these eating habits, when used correctly, reduce the risk of occurrence CVDs. As a consequence of following diets there have been reported effects such as lower blood pressure, reduction in glucose, total cholesterol, LDL and triglycerides levels. However, the most recommended dietary patterns in prevention and treatment of CVD are MD and DASH diet. These are the best studied and there are the most evidence that its components may reduce the risk. Patients with these eating habits presented lower level of specific cholesterol fraction, what contributed to the reduction of the CVDs incidence rate. In the case of the DASH diet, antihypertensive properties were also observed. Simultaneously both provide all the necessary nutrients and there are no negative effects of the use. Ketogenic is an alternative diet which is also confirmed to have a positive effect on the cardiovascular system, but the supply of fruit and vegetables is insufficient, what may cause hypovitaminosis, dehydration, bone impairment and increased exposure to free radicals. Other side effects include constipation, hyperuricemia, nausea, and vomiting. A vegetarian diet is increasingly being recommended in CVD prevention, however an improperly balanced vegetarian diet can cause numerous nutritional deficiencies.

Despite the large amount of evidence supporting the effectiveness of these diets, long-term studies of the effect of various diets on the incidence of CVD are still needed.

Acknowledgements

Conflict of interest statement
The authors declare no conflict of interest.

Funding sources
There are no sources of funding to declare.

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