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Key Elements of Plant-Based Diets Associated with Reduced Risk of Metabolic Syndrome

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Abstract Approximately 20 %–25 % of adults worldwide have metabolic syndrome. Vegetarian and vegan diets have demonstrated effectiveness in improving body weight, glycemic control, and cardiovascular risk factors, as compared with conventional therapeutic approaches, and are potentially useful in the prevention of metabolic syndrome. This article consists of two steps: (1) a review of the literature on studies examining vegetarian and vegan diets and metabolic syndrome and (2) a review of foods and nutrients that are protective against or associated with metabolic syndromes that may help to explain the beneficial effects of plant-based dietary approaches for metabolic syndrome. The present review found eight observational research studies, and no intervention studies, examining the association of plant-based dietary approaches with metabolic syndrome. These studies, conducted mostly in Asian populations, yielded varying results. The majority, however, found better metabolic risk factors and lowered risk of metabolic syndrome among individuals following plant-based diets, as compared with omnivores. Some dietary components that are lower in the diets of vegetarians, such as energy intake, saturated fat, heme iron, and red and processed meat, may influence metabolic syndrome risk. In addition, plant-based diets are higher in fruits, vegetables, and fiber, which are protective against the development of metabolic syndrome.

Keywords Vegetarian · Vegan · Metabolic syndrome · Diet · Nutrition · Plant-based diets

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Introduction

Approximately one in four adults in the United States (U.S.) has metabolic syndrome, which is considered a risk factor for atherosclerotic cardiovascular disease [1]. In addition, 20 %–25 % of adults worldwide have metabolic syndrome, which doubles the risk for having a heart attack and triples stroke risk [2]. Components of metabolic syndrome may include dyslipidemia, elevated blood pressure, insulin resistance, abdominal obesity, and proinflammatory and thrombotic states [3]. Lifestyle therapies are considered essential for the treatment of metabolic syndrome, including approaches to improve dietary intake, body weight, lipids, insulin resistance, and hypertension [4] Plant-based diets, such as vegan and vegetarian diets, are a dietary strategy that may be useful in treating and preventing the development of metabolic syndrome. Studies have demonstrated that well-planned vegan and vegetarian diets can provide adequate nutrition and may have health benefits for disease prevention and treatment [5•]. People following vegan and vegetarian diets have lower body mass indices (BMIs), as compared with nonvegetarians, as well as a lower prevalence of type 2 diabetes [6–8]. Clinical trials using vegetarian and vegan diets have demonstrated significant improvements in body weight [9], glycemic control [10], and cardiovascular risk factors [11], as compared with conventional therapeutic approaches (e.g., reduced fat and/or energy diets). Vegan and vegetarian diets have also been used effectively for weight loss and maintenance [9, 12]. While other dietary approaches, such as the Mediterranean diet [13]

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or diets emphasizing a low glycemic index [14], have also shown promise as potential dietary strategies to prevent metabolic syndrome, the present article focuses on vegetarian and vegan diets. Vegetarian and vegan diets may also contain many of the health-promoting nutritional aspects of Mediterranean or low glycemic index dietary approaches, but few studies have reviewed the literature with a focus only on vegetarian and vegan diets.

The goal of the present report is to provide an overview of studies that have examined the use of vegan and vegetarian diets in relation to metabolic syndrome prevalence or treatment. In addition, key dietary components of vegetarian and vegan diets, which may be beneficial in the prevention and treatment of metabolic syndrome, are discussed. Table 1 provides the descriptions of different dietary approaches employed by the studies examined in this article and also provides sample dinner meals for each diet type.

Method

This study consisted of two steps. The first step was to examine the literature on the use of vegetarian and vegan diets in the prevention or treatment of metabolic syndrome. For this step, we conducted a search of the Medline database using a combination of the terms "vegan" or "vegetarian" and "metabolic syndrome," for articles published from 1992 to February 2014. The search yielded a total of 31 articles, which were reviewed for possible inclusion using a three-step process: examining the title, the abstract, and then the full text. We also used synonymous search terms suggested by the National Library of Science–Medical Subject Headings (MeSH) to increase the range of data collected. MeSH suggested "syndrome x" as a term interchangeable with "metabolic syndrome" but yielded no additional relevant studies. We also used the bibliographies of the studies retrieved to further increase the range of data collected.

Reports published in languages other than English were reviewed if English translations were available. The systematic search included articles if the reported studies (1) were among adults, (2) involved vegan or vegetarian diets, (3) delineated the number of participants as well as their ages and clinical status, (4) examined metabolic syndrome and at least three of the diagnostic criteria for metabolic syndrome (e.g., elimination of studies that only examined HDL cholesterol), (5) reported the duration and type of trial, (6) discussed at least one comparison group, and (7) included information about the statistical significance of diet group differences for metabolic syndrome. Eight studies met all of the inclusion criteria and were included in the review. A data extraction form was developed to collect information from articles on 11 categories, including author, year of publication, number of participants for each dietary pattern, and metabolic syndrome components. Also, metabolic syndrome and its definition according to respective articles were included in the data extraction process, with primary consideration of the National Cholesterol Education Program Adult Treatment Panel III criteria [3] for classification purposes. Observational studies

Table 1 Description of the diets utilized in studies examining plant-based dietary approaches and metabolic syndrome and example dinner meals for each diet

Dietary Approach	General Definitions of Diet Patterns	Example Dinner Meal
Vegan diet (vegan)	Does not contain any animal products (meat, fish, poultry, eggs, or dairy) but emphasizes plant-based foods, such as fruits, vegetables, whole grains, and legumes/beans.	• Stir-fry made with broccoli, carrots, pineapple, cashews, and tofu over brown rice • Side of applesauce
Vegetarian diet (veg)	Does not contain meat, fish, or poultry but does contain eggs and dairy, in additionto plant-based foods, such as fruits, vegetables, whole grains, and legumes/beans.	• Stir-fry made with broccoli, carrots, pineapple, cashews, and tofu over brown rice • Side of yogurt
Pesco-vegetarian diet (pesco-veg)	Does not contain meat or poultry but does contain fish and shellfish, eggs, and dairy, in addition to plant-based foods, such as fruits, vegetables, whole grains, and legumes/beans.	• Stir-fry made with broccoli, carrots, pineapple, cashews, and shrimp over brown rice • Side of yogurt
Semivegetarian diet (semiveg)	Contains all foods, including meat, poultry, fish and shellfish, eggs, and dairy, in addition to plant-based foods, such as fruits, vegetables, whole grains, and legumes/beans. However, red meat and poultry are very limited.	• Stir-fry made with broccoli, carrots, pineapple, cashews, and chicken over brown rice • Side of yogurt
Omnivorous diet (omni)	Contains all food groups.	• Stir-fry made with broccoli, carrots, pineapple, cashews, and beef over brown rice • Side of yogurt

were included. However, the literature search revealed no intervention studies with adequate details about metabolic syndrome or at least three of its components as an outcome.

The second step of this report was to conduct a review of dietary components that have been associated with metabolic syndrome and have been found to be differentially higher or lower in vegan or vegetarian diets. This included both nutrients (macro- and micronutrients) and food groups (e.g., fruits and vegetables).

Results

Review of Studies Examining Vegetarian and Vegan Diets Associated with the Reduction of Metabolic Syndrome Risk

From the review of the literature, eight studies were identified as meeting inclusion criteria. Table 2 provides an overview of the eight relevant studies and the findings for each component of metabolic syndrome, as well as for metabolic syndrome occurrence. Of the three studies finding significant differences among or between dietary groups [15••, 16••, 17] and a fourth study demonstrating that vegetarians met significantly fewer of the metabolic syndrome criteria than did omnivores [18], the prevalence of metabolic syndrome or the criteria for metabolic syndrome among vegetarians and vegans was lower, as compared with those following omnivorous or other diets. With the exception of one study [17], which found that vegetarians and omnivores had a lower risk of metabolic syndrome than did vegans, no studies we reviewed found omnivorous diets to be more protective against metabolic syndrome than vegetarian or vegan diets.

Half the studies (n=4) [19••, 20–22], however, were inconclusive. Vegan and vegetarian diets appear to have the most significant impact on measures of blood pressure and fasting glucose, followed by waist circumference, but have less of an impact on triglycerides and HDL cholesterol. The majority of the studies found significantly better blood pressure [15••, 16••, 18, 20, 21] and fasting glucose [15••, 16••, 17, 18, 19••, 21] among vegetarians and vegans. Three studies found significantly lower waist circumferences in vegetarians and vegans, as compared with other diets [15••, 16••, 18], and two found better triglyceride levels [16••, 21]. No studies found significantly better HDL cholesterol levels among vegetarians or vegans, as compared with omnivorous or other diets.

Dietary Components Associated with Vegan and Vegetarian Diets That May Be Beneficial for Metabolic Syndrome Treatment and Prevention

Individuals with metabolic syndrome tend to consume diets that are high in fat and fried foods and low in fiber, fruits, and vegetables [23]. Most research examining diet and metabolic syndrome to date, however, has primarily focused on single foods or nutrients, such as nuts [24] or fiber [25]. And while randomized controlled trials have examined the use of vegan or vegetarian diets with other endocrine-related conditions, such as type 2 diabetes [26] or polycystic ovary syndrome [27], no clinical trials to date have examined the use of vegan or vegetarian diets for the prevention or treatment of metabolic syndrome.

A change in a single nutrient (such as decreasing dietary fat or increasing fiber) may not be sufficient enough to promote significant changes in metabolic syndrome risk. There may be several nutrients and dietary components that are working together to have a protective effect. This may be one reason why vegetarian and vegan diets may be protective against the development of metabolic syndrome. There are several components of vegetarian and vegan diets that may make them favorable dietary approaches for metabolic syndrome. These include both nutrients and food groups that are typically lower or absent in plant-based eating styles (energy intake, saturated fat, meat, and heme iron) or higher in plant-based eating styles (fruits, vegetables, and fiber).

Energy Intake and Body Weight

Having energy intake (kcals) match energy expenditure is the key component of energy balance and maintaining a healthy body weight. Because excess body weight is associated with metabolic syndrome [28], consuming a diet that matches energy needs is important for preventing metabolic syndrome. One dietary advantage of following vegan or vegetarian diets may be consuming a diet lower in energy content, as compared with omnivorous diets. Differences in energy intake among individuals following vegan or vegetarian diets, as compared with omnivorous diets, as related to body weight, however, have shown varying results. In several randomized controlled trials comparing vegan or vegetarian diets with omnivorous dietary approaches, significant weight loss has occurred in the absence of significantly different changes in reported energy intake between groups [29–32]. This is different from what has been seen in studies using traditional weight loss diets (reduced energy omnivorous diets), which have demonstrated a greater reduction in energy intake corresponding to greater weight loss [33]. In observational cohort studies, among Adventist Health Study-2 participants following five different diets (see Table 1), BMI was found to be lowest among vegans and highest among omnivores; yet energy intake did not significantly differ among the five groups, averaging 2,000 kcal/day, with the exception of lower energy intake among semivegetarians [34•].

This difference in body weight without observed differences in energy intake could possibly be explained by higher levels of physical activity among vegan and vegetarian participants, which have been observed in some of the cohort

Table 2 Summary of studies examining the association of vegetarian and vegan diets with metabolic syndrome and associated risk factors

Study	Country, Year	Vegetarian Population Studied (*N*)	Comparison Group(s) Studied (*N*)	Age (years) (±*SD* or range)	Significantly better metabolic profile for each metabolic syndrome risk factor denoted by V for vegetarian or vegan diet or C for comparison. NS for not significantly different and DNM for not measured.					
					Waist Circumference	Triglycerides	HDL Cholesterol	Blood Pressure	Fasting Glucose	Metabolic Syndrome Occurrence
Kim and Bae [18]	Korea, 2012	59 postmenopausal, female vegetarians	48 postmenopausal, female age-matched omnivores	Vegetarians, 63.03±9.34; Omnivores, 62.13±8.28	V	NS	NS	V	V	NS[1, a]
Chiang et al. [15••]	Taiwan, 2013	391 female vegetarians	315 female omnivores	56.4±8.4	V	NS	C	V (systolic only)	V	V[2]
Sebekova et al. [20]	Slovakia, 2006	90 vegetarians	46 omnivores	Vegetarians, 35.1–40.3; Omnivores, 33.5–40.7	DNM	NS	NS	V	NS	NS[3]
Gadgil et al. [19••]	U.S., 2013	91 vegetarians	59 omnivores	45–84 Vegetarians, 58.1±8.46; Omnivores, 55.8±7.25	NS (assessed as hip-to-waist ratio)	NS	C	DNM	V	NS[4]
Rizzo et al. [16••]	U.S., 2011	270 vegetarians; 124 semivegetarians	379 omnivores	Mean age 60 (range 30–94)	V (and semivegetarians)	V	NS	V	V	V[5]
Huang et al. [22]	Taiwan, 2011	269 vegetarians	802 omnivores	56.4±8.4	NS	DNM	NS	NS	NS	NS[1]
Krajcovicova-Kudlackova et al. [21]	Slovakia, 2011	45 vegetarians	38 omnivores	Omnivores, 63.4±0.5; Vegetarians, 65.2±0.5	DNM	V	NS	V (systolic only)	V	DNM
Shang et al. [17]	China, 2011	1,116 vegans	2,461 pesco-vegetarians, 4,313 vegetarians, 8,5319 omnivores	Omnivores, 36.8±11.8, Pesco-vegetarians, 43.5±13.9; Vegetarians, 37.9±14.4; Vegans, 44.1±14.9	C[b]	C[b]	C[b]	C[b]	V	C[1]

Note. Criteria used for metabolic syndrome:

[1] National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) criteria for metabolic syndrome applying Asian guidelines for waist circumference and/or glucose

[2] Modified NCEP and International Diabetes Federation (IDF) definition for Asians

[3] World Health Organization (WHO) criteria

[4] Criteria used for metabolic syndrome not determined

[5] NCEP ATP III 2001 criteria

[a] NCEP score, as represented by the number of criteria for metabolic syndrome each person met, was significantly lower in vegetarians than in omnivores.

[b] Comparison was between those following a vegan diet versus comparison diets, which included vegetarian, pesco-vegetarian, and omnivorous diets.

studies [34•, 35]. Physical activity, however, was controlled for in the randomized trials either giving participants identical exercise recommendations [31] or holding exercise levels constant across experimental groups [29, 30, 32]. Other explanations for differential weight loss effects among diets without differences in reported energy intake or expenditure could include the following: unmeasured outcomes, such as changes in the thermic effect of food [36]; differential changes in the gut microbiome, which could affect digestibility of energy-containing foods [37, 38]; a higher intake in foods, which may increase lipolysis and fat oxidation [39]; or discrepancies between the reported energy values for foods commonly consumed on vegan diets (such as nuts) in nutrient databases and actual energy values of these foods [40]. Not all studies examining BMI, energy intake, and vegan/vegetarian diets have found similar energy intakes among diet groups despite differences in body weight. For example, in the European Prospective Investigation into Cancer and Nutrition (EPIC–Oxford) cohort, BMI and energy intake were significantly different among four different diet groups (vegan, vegetarian, pesco-vegetarian, and omnivore), with vegans having the lowest BMI and energy intake, as compared with omnivores [35].

Dietary Saturated Fat

Some studies [41, 42], but not all [43], have observed that diets high in saturated fat are associated with increased risk of developing metabolic syndrome. Both observational [34•, 44, 45] and experimental [29, 30, 46] studies have consistently demonstrated lower saturated fat intake among individuals following a vegan diet and, to a lesser extent, a vegetarian diet, as compared with omnivores. In the U.S., cheese is one of the largest contributors to saturated fat intake, followed by beef, pork, processed meat, and other high-fat dairy products (whole milk, ice cream) [47–49]. Because individuals following a vegan diet avoid all of these food groups and those following a vegetarian diet avoid most of them, this allows for diets lower in saturated fat. The U.S. Dietary Reference Intakes do not specify a recommended level of dietary saturated fat but state that intake should be "as low as possible while consuming a nutritionally adequate diet." Other sources, such as the American Heart Association and the Institute of Medicine, recommended that adults and children maintain a diet with <10 % of energy being derived from saturated fat [50, 51]. Current intakes in the U.S. exceed this level (mean of 11 % energy from saturated fat) [52]. Reducing energy from saturated fat can be difficult, even on therapeutic diets targeting reductions in cardiovascular disease risk. In a 74-week randomized trial comparing adherence to a low-fat vegan diet or the dietary approach recommended by the American Diabetes Association (ADA), most participants in the ADA group did not meet ADA diet criteria, due to exceeding saturated fat recommendations [53]. Those following the vegan diet had mean percentage of energy from saturated fat of 5.0±0.5 [53].

Dietary Fiber

Diets high in dietary fiber are associated with lower risk of developing metabolic syndrome [43, 54, 55]. In the U.S., average fiber intake falls well below the recommended levels for adults of 25 g/day for women and 38 g/day for men [56]. Mean fiber intake ranges from 15 to 17 g/day in U.S. adults [57], with higher fiber intake associated with lower inflammation [57] and overweight and obese individuals being less likely to consume high-fiber diets [58]. Following a vegetarian or vegan diet means that meat (and other animal products in the case of vegan diets) eliminated from the diet must be replaced with other sources of protein. Vegetarian protein-rich foods include beans, peas, lentils, soy foods, nuts, and seeds. One cup of cooked legumes generally provides a ratio of 1 g of fiber to 1 g of protein (e.g., 1 cup of cooked black beans contains 15 g of fiber and 15 g of protein) [59]. Legumes, however, are not a common source of protein in the U.S. diet, with beef, poultry, and milk being the top three sources and legumes not even appearing in the top ten protein sources for adults in the U.S. [60]. Replacing some or all of animal protein with plant-based protein sources could assist with increasing fiber intake. For example, replacing just 2 ounces of cooked ground beef with 1 cup of cooked beans (both with 15 g of protein) would double the mean fiber intake of most adults in the U.S. Making meals vegetarian by replacing animal products with legumes has been shown to be a potentially cost-effective way to improve fiber levels of meals [61]. Both observational [34•, 44, 45] and experimental [29, 30, 46] studies have demonstrated significantly higher fiber intakes among vegetarians and vegans, as compared with omnivores.

Fruit and Vegetables

High intake of fruits and vegetables is associated with a reduced risk of metabolic syndrome [62, 63]. Individuals following vegetarian and vegan diets tend to have higher fruit and vegetable intake than those following omnivorous diets [29, 30, 34•, 44, 45, 64–66]. High intake of fruits and vegetables can provide individuals with important antioxidants, which may help to prevent inflammation in the body [62]. In addition, fruits and vegetables are a good source of fiber, which can also assist with preventing metabolic syndrome and other cardiovascular diseases [63]. In a 22-week randomized controlled trial among adults with type 2 diabetes, participants randomized to a low-fat vegan diet increased their vegetable intake by more than three servings/day and their fruit intake by more than one serving/day, as compared with individuals randomized to the dietary approach recommended

by the ADA, who saw no improvements in fruit and vegetable intake [29].

Meat Intake

Meat consumption, particularly red and processed meat, has been associated with increased risk of metabolic syndrome and type 2 diabetes [67–70]. Elimination of meat from the diet, which occurs when an individual follows a vegan or vegetarian diet, is one potential strategy to mitigate the risk of developing metabolic syndrome. Even individuals following semivegetarian or pesco-vegetarian diets consume significantly less animal protein than do omnivores, although intakes are even lower among those following vegetarian or vegan diets [34•]. This pattern of meat intake going from highest in omnivores, intermediate in semi- or pesco-vegetarians, and lowest in vegetarians and vegans may be one explanation for the same pattern emerging for these diet groups in the Rizzo et al. study for rates of metabolic syndrome (highest in omnivores, intermediate in semivegetarians, and lowest in vegetarians) [16] and type 2 diabetes [7].

Heme Iron

Intake of heme iron, as well as increased serum ferritin levels, has been associated with increased risk of developing metabolic syndrome and type 2 diabetes [71–74]. Increases in the body's iron stores are associated with decreases in insulin sensitivity, whereas decreases in iron stores improve insulin sensitivity [67]. Nonheme iron is easier for the body to regulate and is more responsive to enhancers (both dietary enhancers and specific iron need of the individual) and inhibitors (such as phytic acid) [5•]. Heme iron is found only in animal foods and, therefore, is not present in vegetarian and vegan diets. While heme iron is more absorbable than nonheme iron, most studies do not demonstrate that serum ferritin levels of vegetarians are at suboptimal levels [5•]. Both observational [34•, 44, 45] and intervention [29, 30, 46] studies have shown higher or similar iron intakes between vegetarians and vegans, as compared with omnivores, with the difference being that the vegetarian and vegan diets contain only nonheme iron. Decreasing sources of heme iron in the diet is another potential strategy for decreasing risk of metabolic syndrome and another reason why vegetarian and vegan diets may be protective against metabolic syndrome.

Conclusions

While several of the studies examined in this review of the association of vegetarian and vegan diets with metabolic syndrome showed a protective effect of vegetarian diets [15••, 16–18], not all studies have found a consistent relationship between a vegetarian diet and lowered risk of having any of the criteria for metabolic syndrome [19••, 20, 22]. In the case of the Shang et al. study [17], vegetarian and omnivore participants had a lower risk of having metabolic syndrome than did vegan participants. It is possible that this inconsistency in results among metabolic syndrome studies is due to the heterogeneity that is present when all vegetarian diets are collapsed into one group (vs. examining differing patterns of vegetarian diets, such as vegan and vegetarian) or the variability in patterns of food intake by geographic location [75]. In addition, it appears that differences in the risk factors for metabolic syndrome are more pronounced in studies conducted in Western populations, which may be due to dietary factors being more similar between vegetarians and nonvegetarians in Asian populations [17]. Conversely, this could be due to the differences between dietary intakes of Western omnivores and Western vegetarians being much greater, allowing for more robust changes to happen when someone following a Western omnivorous diet switches to a more plant-based approach. A lack of findings from some studies could be also be due to the observational nature of the research, as opposed to using a randomized, prospective design. In fact, we found no randomized controlled trials using plant-based dietary approaches with metabolic syndrome as a primary outcome.

This review has provided an overview of potential dietary components that may play a role in the protective effect of plant-based diets. This includes lower energy intake, saturated fat, heme iron, and an absence of red and processed meat intake among vegetarian and vegans, as compared with other dietary patterns. In addition, higher intakes of fiber and fruits and vegetables among those following vegan or vegetarian diets may be protective against metabolic syndrome. Future research should test these dietary approaches in a more controlled manner, which would allow for a better understanding of how transitioning to these type of dietary approaches impacts risk factors of metabolic syndrome. While examining the prevention of metabolic syndrome using a randomized design may be difficult due to the amount of time needed to detect an effect, a randomized design could be used to examine the treatment of metabolic syndrome. The review of studies included in this report found that vegan and vegetarian diets had the most impact on blood pressure and fasting glucose. A randomized design could assess whether vegetarian and vegan diets also have the greatest impact on these parameters of metabolic syndrome when used for treatment or whether other parameters are impacted as well. Conducting a randomized controlled study examining the impact of plant-based dietary approaches on metabolic syndrome, combined with the epidemiological evidence, could help strengthen the evidence base for potential dietary strategies for the prevention and treatment of metabolic syndrome.

Compliance with Ethics Guidelines

Conflict of Interest Gabrielle Turner-McGrievy and Metria Harris declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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