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Original article

Adherence to Vegetarian Diet and Weight Loss: A Meta-Analysis

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Abstract. *Background:* Veganism and vegetarianism, which are becoming popular worldwide, are not only a diet but a lifestyle, a philosophy of life, and an ethical approach. A vegetarian diet is thought to be the solution to the increasing food requirements of the growing population. In this meta-analysis, we evaluated the correlation between a vegetarian diet and weight loss. *Methods*: For the meta-analysis, PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines were followed. We conducted a comprehensive review of the literature published in PubMed, Science Direct, and ResearchGate databases. Only randomized controlled trials and cohort studies published after 2007 were included in the meta-analysis if they reported the results on weight loss and contained appropriate statistical analysis data. *Results:* The meta-analysis included 11 studies comprising of 934 participants, of which 10 were randomized controlled trials, and 1 was a cohort study. Applying the random effects model, it was concluded that compliance with the various types of vegetarian diets had a positive effect on weight loss. The effect size of the relation between vegetarian diet and weight loss was 0.954. It is between the lower limit (0.393) and the upper limit (1.515) values for the effect sizes of the relevant studies in the 95% confidence interval. There was no publication bias as the circles (representing each study) shown in the Funnel plot graph were spread symmetrically around the vertical line in the middle. *Conclusions:* The vegetarian diets (vegan and lacto-ovo vegetarian diets) had beneficial effects on weight loss. One possible reason responsible for weight loss could be the varied nutritional composition, for example, high fiber and low protein diet. However, further interventional studies with vegetarian diets are warranted to investigate their long-term effects and clinical implications on weight loss.

Key words: vegetarian diet, weight loss, meta-analysis

Introduction

Vegetarianism is a practice that generally includes the consumption of plant-based foods rather than animal-based foods. Although vegans (total vegetarians) abstain from all animal-based products, semivegetarians consume both plant and animal products, such as red meat, fish, chicken, eggs, and milk and milk products in limited amounts (1).

According to the World Health Organization, health is defined as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity." The principal reason for choosing a vegan/vegetarian diet is people's concern for health. According to many studies, the health of people with a vegan/vegetarian diet is comparatively better than those who eat meat (2). Vegetarian diets constitute an important part of nutrition in Western countries, and many studies have demonstrated their short and long-term benefits to health (3). Most importantly, all these studies emphasized on attention to adequate and balanced nutrition. It has been suggested

that lack of attention might lead to vitamin B12 deficiency, anemia, and osteoporosis in vegetarians, especially in vegans (2). However, diet alone does not determine the health status of individuals as there may be many other factors that affect health; therefore, more detailed research is required on this subject. People choose a vegan / vegetarian diet for various reasons; some prefer it as it is healthier, while others prefer it for ethical reasons (considering that animals should be respected). Apart from these reasons, other factors could also influence the adoption of this lifestyle (2).

Among Adventists who preferred a vegetarian diet, 30% of the population had a low body mass index (BMI). However, the BMI of both men and women increases when the frequency of meat consumption increases. In the Adventist Health Study-2 (AHS-2) cohort, comprising of >96,000 participants, the BMI of vegetarians was found to be approximately 2-4 points lower compared to the non-vegetarians (4). The Oxford Vegetarian Study showed that compared to male and female vegetarians of all age groups, non-vegetarians had higher body mass index values. In a study with 37875 adults, it was observed that meat-eating participants had the highest mean body mass index, followed by vegetarians and vegans (5). According to the Oxford-European Prospective Investigation into Cancer and Nutrition (EPIC), weight gain over a 5-year period was the least in a health-conscious cohort whose diet involved restricted consumption of animal food. In a comprehensive study conducted in Britain, no remarkable changes in body weight or BMI were observed in people who switched to a vegetarian diet in adulthood in contrast to those who are vegetarians throughout their lives. A lower BMI has been demonstrated in people following a vegetarian diet for ≥5 years (6). Among the Adventists in Barbados, the prevalence of obesity in the vegetarian population was 70% lower over a 5-year period compared to the meat-eating population. In contrast, people following a vegetarian diet for <5 years had body-weight similar to those who ate meat (7). In postmenopausal women, long-term weight loss was realized due to a low-fat, vegetarian diet compared to the traditional National Cholesterol Education Program diet. Individuals following a vegetarian diet have a lower BMI since they consume a substantial amount of fruits and vegetables that are fiber-rich, low-energy foods due to the abundant consumption of, such as vegetables and fruits (7). There is a requirement for further intervention studies concerning vegan / vegetarian diets to understand their long-term effects and clinical outcomes on weight loss (8). We performed a comprehensive literature search, followed by a meta-analysis using the appropriate literature (randomized controlled trials and cohort studies) to evaluate the correlation between a vegetarian diet and weight loss.

Materials and Methods

Literature Search Strategy

We conducted a comprehensive literature search to extract relevant studies in the English language. Only studies published in PubMed, Science Direct, and ResearchGate databases, from 2007 until 2021, were considered. The following keywords were used for the literature search: "vegan diet" OR "vegetarian diet" OR "plant-based diet" AND "weight" OR "weight loss." Participants belonging to all age groups were considered. In addition, references mentioned in the original studies were manually searched.

Inclusion Criteria

Titles and abstracts of publications on the relationship between vegetarian diet and weight loss were reviewed. If an abstract was found to be appropriate, the corresponding full text was reviewed. The selected studies were deemed eligible for this meta-analysis if they were either randomized controlled trials or cohort studies, the results focused on weight loss, data about the mean and standard deviation was available, and the studies were conducted after 2007.

Exclusion Criteria

Comments, reviews, case-control, cross-sectional, and unpublished studies were excluded from the analysis. A total of 525 articles were retrieved in the initial search. We selected 20 potentially appropriate articles after a thorough screening, which

included the production of copies, summary and title search, removal of studies prior to 2007, and removal of studies without data on weight loss. Nine of these articles were not included in the study due to the lack of appropriate statistical data. Ultimately, following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, a total of 11 studies were found eligible for the meta-analysis (Figure 1). The articles reviewed included "*vegetarian diet*" (17, 18, 19), "*vegan diet*" (15, 21; 23), "*lacto-ovo vegetarian diet*" (16, 22, 24), and "*plant-based diet*" (20, 25).

Data Extraction

Author information, year of publication, number of participants, geographical location of the study, study design, participants age range, experimental and control group diet models, study evaluation method, and results including mean and standard deviation values were extracted from the selected studies.

The Newcastle Ottawa Scale and the Jadad Score were respectively used for assessing the quality of the cohort studies and randomized studies included in this meta-analysis.

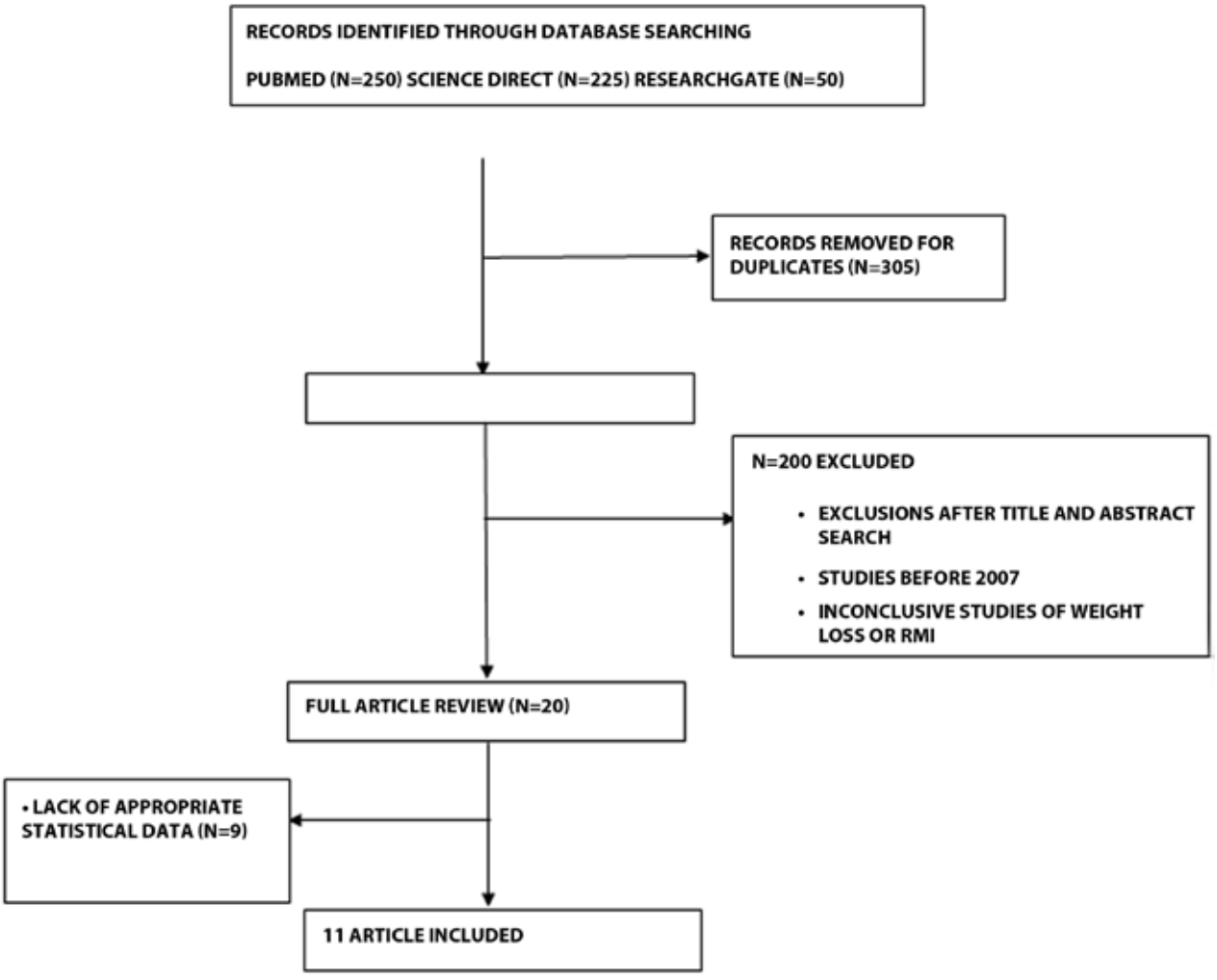

Figure 1. PRISMA flow diagram representing the literature review on the association of weight loss with a vegetarian diet and the process of including the screened studies in the meta-analysis

Statistical Analysis

For the statistical analysis, data from the selected articles were entered into the Comprehensive Meta-Analysis (CMA) licensed software The CMA program was used to obtain the general effect sizes, forest plot, funnel plot graphics.

H1: A statistically significant positive correlation exists between weight loss and a vegetarian diet.

H2: Publication bias between variables does not exist.

Cohen's effect size was used for the evaluation of the effect value. Accordingly, the effect values are:

0.00 <0.10 effect size value: very weak effect;

0.11 <0.30 effect size value: weak effect;

0.31 <0.50 effect size value: medium effect;

0.51 <0.80 effect size value: strong effect;

≥0.81: very strong effect (9).

The heterogeneity of the articles included in the study was evaluated. Q statistics have been used for effect size calculation in meta-analysis studies, to make decisions about the fixed effect and random effect model, and the evaluation of heterogeneity between studies. We tested whether the Q statistics showed the overall effect. As a result of the analysis, if the significance value (p) is below the critical value, this result can be interpreted that all studies do not show the same effect (10,11). In this case, it can be said that there is heterogeneity between studies. The I^2 statistic shows the information about the ratio of heterogeneity. Random effects model is used if the individual study results included in the meta-analysis are heterogenous, and fixed effects model is used if they are homogeneous (12).

Publication bias in the studies was examined with a funnel plot. The funnel plot will be symmetrical if there is no publication bias. Publication bias in studies causes an asymmetrical appearance in the graph, and one corner of the graph is left blank compared to the other corner (13).

Results

A total of 525 articles were retrieved in the literature review. After screening, 11 articles, including a total of 934 participants and examining the relationship between vegetarian diet and weight loss, were included in the study. Ten of the articles included were randomized controlled trials, and 1 was a cohort study. The main characteristics of these studies, such as type of study, participant age range, sample size, country of study, experimental and control group characteristics, evaluation criteria, and other features, are shown in Table 1. Studies included had been carried out between 2007-2021.

The age range of the study participants was between 18 and 79 years. In the experimental group of the selected studies, 3 of them had a "vegetarian diet", 3 had a "vegan diet", 3 had a "lacto-ovo vegetarian diet", and 2 of them had a "plant-based diet.". The geographical locations of the studies included the United States of America, Sweden, South Korea, Czechia, Italy, and New Zealand.

Firstly, the heterogeneity of the studies was tested. Based on the analysis results, the significance value and the choice of model, fixed or random effect, were examined. The statistical significance of the meta-analysis is presented in Table 2. Considering the Q (160.645) and I^2 (93%) values, the random effects model was chosen as the impact model.

Table 2 presents the 95% confidence interval and Fisher's Z values for the correlation between vegetarian diet and weight loss. The effect size value was 0.954, showing a positive relationship between the vegetarian diet and weight loss. It is between the lower limit (0.393) and the upper limit (1.515) values for the effect sizes of the relevant studies in the 95% confidence interval. The overall effect size was found to be significant ($p = 0.001$). In light of the findings in Table 2, it can be concluded that a statistically significant positive relationship exists between a vegetarian diet and weight loss (Figure 2). It has a very strong level of influence, considering its effect size. Thus, the H1 hypothesis was accepted.

In meta-analysis studies, the funnel plot is first evaluated for publication bias. Figure 3 shows that the circles in the funnel plot are spread symmetrically around the vertical line in the middle, which proves that our meta-analysis was devoid of publication bias (14).

Table 1. General characteristics of the studies included in the meta-analysis

Study	Total n	Female n	Male n	Country	Age (Years)	Intervention Group	Control Group	Duration (weeks)	Characteristics of the participants
Barnard et al. 2018 (15)	45	24	21	USA	30-79	Vegan diet	Portion-controlled diet	20	Type 2 diabetes
Burke et al. 2007 (16)	176	153	23	USA	18-55	Calorie-restricted, low-fat, lactoovovegetarian diet	Standard, calorie-restricted, low fat, omnivorous diet	72	Overweight and obese
Djekic et al. 2020 (17)	31	2	29	Sweden	61-70	Vegetarian diet	Isocaloric meat diet	4	Ischemic heart disease
Ferdowsian et al. 2010 (18)	113	93	20	USA	21-65	Low-fat, vegetarian diet	Other therapeutic diets	22	Overweight / Type 2 diabetes
Kahleova et al. 2010 (19)	74	39	35	Czechia	30-70	Vegetarian diet	Conventional diabetic diet	24	Type 2 diabetes
Kahleova et al. 2018 (20)	75	67	8	USA	25-75	Low-fat, plant-based diet	No diet changes	16	Overweight adults with no history of diabetes
Mi-Lee et al. 2016 (21)	93	75	18	South Korea	30-70	Vegan diet	Conventional diet	12	Type 2 diabetes
Sofi et al. 2018 (22)	118	92	26	Italy	18-75	Lacto-ovo vegetarian diet	Mediterranean Diet	12	Overweight with a low-to-moderate risk of cardiovascular diseases
Shah et al. 2018 (23)	100	15	85	USA	35-85	Vegan diet	American Heart Association–recommended diet	8	Coronary artery disease
Sushama et al. 2013 (24)	143	127	16	USA	18-55	Fat-restricted, lacto-ovo-vegetarian diet	Standard calorie- and fat-restricted diet	26	Overweight/obese
Wright et al. 2017 (25)	65	39	26	New Zealand	35-70	Whole food plant-based diet	Standard medical care	52	Obese or overweight along with at least Type 2 diabetes, ischemic heart disease, hypertension, or hypercholesterolemia.

The Egger's linear regression test is one of the methods used to evaluate publication bias in meta-analyses. Here, we determined the results of the Egger's linear regression test, which were as follows: Intercept = 10.408; t = 2.360; p = 0.425. Another method used for determining the publication bias is the Begg and Mazumdar rank correlations statistics. According to this method, Kendall's Tau-b coefficient should be close to 1 and the p-value >0.05. In this study, Kendall's Tau-b was 0.43 and p = 0.061, which showed

Table 2. Homogeneity vs. heterogeneity test results of the association between vegetarian diet and weight loss

Model	95% Confidence Interval of Effect Size				Heterogeneity Test				
	No. of studies	Effect Size (r)	Lower limit	Upper limit	Q value (x^2)	0.05 Confidence interval (x^2)	Degrees of freedom (df)	P	I^2(%)
Fixed	11	0.719	0.582	0.857	160.645	18.307	10	0.000	93.775
Random	11	0.954	0.393	0.1515					

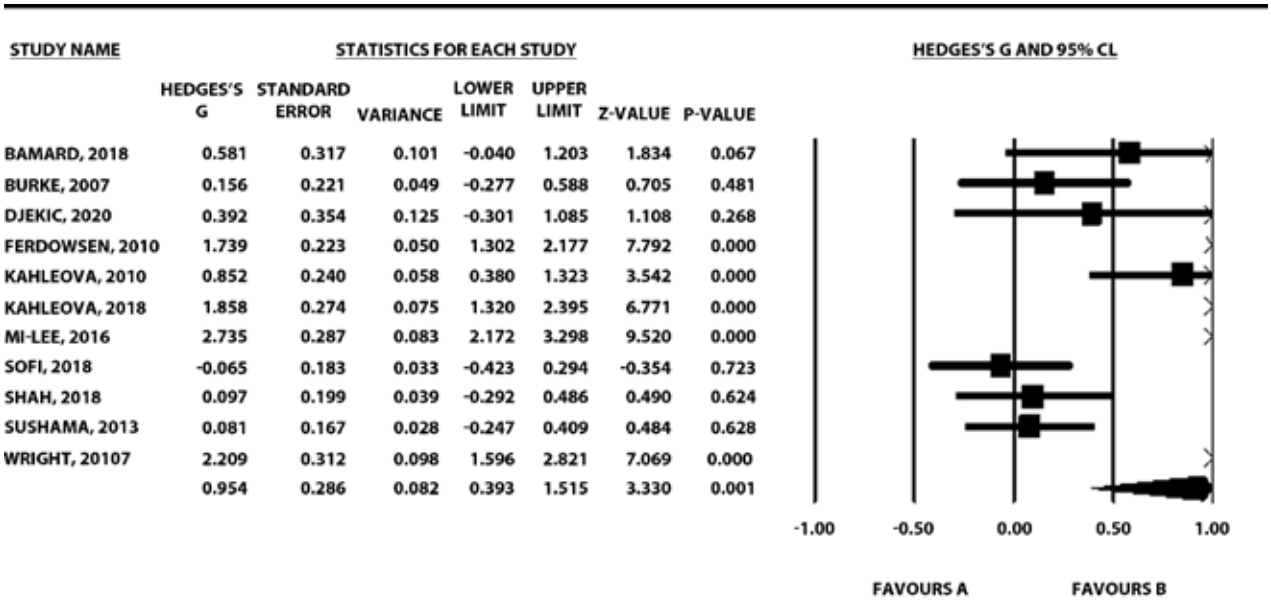

Figure 2. Forest plot showing the effect sizes of the studies.

that this meta-analysis is devoid of publication bias. Considering all these results, it can be concluded that there is no publication bias in this meta-analysis. Thus, the H2 hypothesis was accepted.

Discussion

We conducted this meta-analysis to investigate the correlation between various types of vegetarian diets and weight loss, for which the effect size of 11 relevant studies was calculated. According to the study results, it was concluded that vegetarian diets have a positive effect on weight loss.

In most of the studies examining weight loss following a vegan diet where animal-based products are not consumed at all, and lacto-ovo vegetarian diet, which is one of the vegetarian diets where meat is not consumed but eggs and milk are allowed, it has been concluded that these diets have a positive relationship with weight loss [8]. Nevertheless, in some studies, there was no significant relationship between a vegetarian diet and weight loss.

A study conducted with Type 2 diabetes patients in the USA, where the relationship between glycemic control, weight loss, lipid concentrations, blood pressure, and kidney functions was examined for 20 weeks, the experimental group was provided a vegan

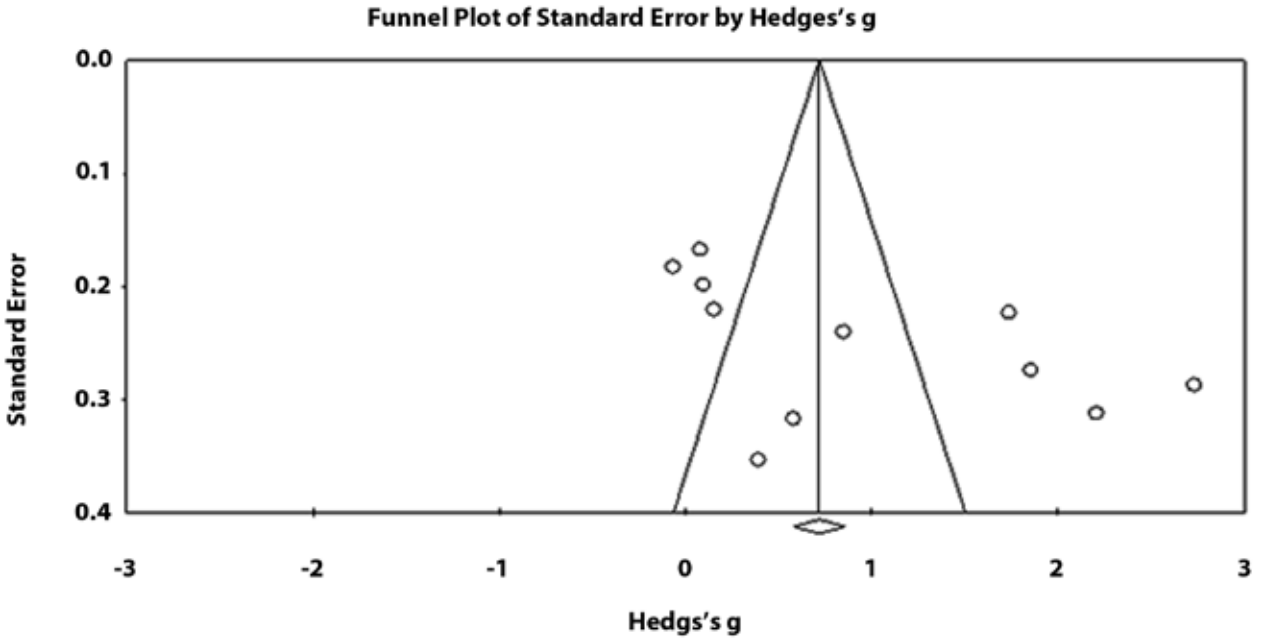

Figure 3. Funnel plot showing publication bias in CMA program

diet. Similar to our study results, weight loss (-6.3 kg) was greater in the experimental group compared to the portion-controlled group (-4.4 kg) (15).

İn another study examining insulin resistance, the experimental group was fed with a low-fat, lacto-ovo vegetarian (LOV-D) diet, and the control group was provided a standard, calorie-restricted, low-fat, omnivorous diet (STD-D) and the weight, cholesterol changes (LDL and HDL cholesterol), and triacylglycerol levels were measured. In this study, no significant difference in weight loss was observed in the experimental group and the control group (16).

In a 22-week study with participants having a BMI ≥25 kg/m^2, the experimental group was provided a low-fat, vegan diet due to which the participants experienced more weight changes (weight loss) compared to the control group participants (mean, -5.1 [SE, 0.6] kg vs. +0.1 [SE, 0.6] kg; p = 0.0001). Large changes in waist circumference were also observed in the experimental group (mean, 24.7 [SE, 0.6] cm vs. +0.8 [SE, 0.6] cm; p = 0.0001). Therefore, it was deduced that a low-fat, vegan diet was effective in reducing body weight and waist circumference (18).

In a meta-analysis examining the relationship between vegetarian diet and weight loss, 12 randomized controlled trials were examined. Reportedly, individuals belonging to the vegetarian diet groups showed a significant weight loss (weighted mean difference: -2.02 kg; 95% confidence interval [CI]: 2.80 to -1.23) compared to individuals belonging to the non-vegetarian diet groups. Similar to the results of our meta-analysis, this study also concluded that the chances of weight loss due to a vegetarian diet is significantly higher compared to non-vegetarian diets (26).

Workers at a company's facilities were randomly assigned to 2 groups: BMI ≥25 kg/m^2 and previous Type 2 diabetes diagnosis. A low-fat, vegan diet was provided to the experimental group, followed by the analysis of the dietary intake, body weight, blood pressure, HbA1C values, and plasma lipid concentrations for 18 weeks. A 2.9 kg reduction was observed in the average body weight in the experimental group, while it was 0.06 kg in the control group. Thus, this study showed that a low-fat, vegan dietary intervention could bring about an improvement in body weight, glycemic control in individuals with Type 2 diabetes, and plasma lipids (27).

In a randomized controlled study, individuals with Type 2 diabetes were randomized into 2 groups to compare the low-fat, vegan diet (experimental group) with the traditional diabetes diet (control group). Changes in body

weight, plasma lipids, and glycemic control were analyzed. The study participants were followed up for 74 weeks. Weight loss was observed in both the groups; however, unlike other studies, the difference was not significant (24.4 kg in the vegan group vs. 23.0 kg in the traditional diet group). Moreover, there was a steady decrease in body weight and plasma lipid concentration (28).

The significance of this meta-analysis is reflected in the increasing interest in vegetarian and vegan diets throughout the world in recent years. Although the popularity of the vegan diet has increased for ethical and health reasons, the contributions of this diet to the environment have not been taken into consideration. Gases like carbon dioxide, methane, and nitrous oxide, which cause global warming, mostly originate from the meat, milk, and egg industry. Likewise, almost half of the water in the world is used by these industries. According to a study conducted at the Oxford University, a complete shift to plant-based products reduces the individual carbon footprint by 73%. Considering the increasing global food and water insecurity and inequality due to numerous environmental and socio-economic problems, it is thought that more people will adopt a vegan / vegetarian diet for the transition to a sustainable life. At the same time, studies have proven that a vegan / vegetarian diet has positive effects on weight loss. It is thought that the number of individuals following vegan / vegetarian diets will increase with the rapid increase in the obesity rate all over the world and the rapid depletion of natural resources.

The meta-analysis is not devoid of limitations. The information obtained could be limited, as only randomized controlled and cohort studies were included, while comments, reviews, case-control, cross-sectional, and unpublished studies were excluded from the analysis. Moreover, only studies in the English language, published after 2007, were considered.

Conclusion

In summary, vegetarian diets comprising of vegan and lacto-ovo vegetarian diets were found to be beneficial for weight loss. One possible reason responsible for weight loss could be the varied nutritional composition, for example, high fiber and low protein diet. Thus, because of this nutritional composition, it can be said that consuming more plant-based food and less animal product can help an individual in controlling weight. However, further interventional studies with vegetarian diets are warranted to investigate their long-term effects and clinical implications on weight loss.

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