Systematic Review and Meta-Analysis

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The relationship between pistachio (*Pistacia vera* L) intake and adiposity

A systematic review and meta-analysis of randomized controlled trials

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Abstract

Background: The aim of the study was to conduct a systematic review to comprehensively evaluate the relationship between pistachio intake and obesity.

Methods: We searched 6 databases and acquired parameters from randomized controlled trials regarding obesity, including body weight, body mass index (BMI), and waist circumference. A fixed-effect model was applied to the meta-analysis for the weighted mean difference (WMD) between a diet with pistachios and a control diet.

Results: Eleven trials including a total of 1593 subjects met the inclusion criteria. Compared to the group on a control diet, the pistachio diet group showed lower BMI values (WMD: −0.18 kg/m^2; 95% confidence interval [CI]: −0.26, −0.11 kg/m^2; I^2 = 29.8%) and no differences in body weight (WMD: −0.22 kg; 95% CI: −0.50, 0.07 kg; I^2 = 0.0%) or waist circumference (WMD: 0.76 cm; 95% CI: −0.11, 1.63 cm; I^2 = 7.0%).

Conclusion: A diet with pistachios reduced BMI and had no significant effects on body weight and waist circumference.

Abbreviations: BMI = body mass index, CI = confidence interval, CNKI = China National Knowledge Infrastructure, IQRs = interquartile ranges, WMD = weighted mean difference.

Keywords: adiposity, diet and foods, human nutrition, meta-analysis, pistachio

1. Introduction

Some research publications report beneficial effects of nut intake in humans, with evidence showing reduced blood cholesterol, blood pressure, and incidence of cardiovascular disease.[1–4] However, nuts contain high levels of fat and are regarded as an energy-dense food. Therefore, long-term nut intake may potentially increase the risk of weight gain and obesity.

Pistachios are attracting a great deal of attention because, compared to other nuts, pistachios have a relatively low fat content (mainly from polyunsaturated and monounsaturated fatty acids) and energy levels but higher amounts of fiber (both soluble and insoluble forms), potassium, phytosterol, γ-tocopherol, vitamin K, lutein, and carotenoids.[5] Some researchers have shown that pistachios also influence obesity indexes, including body weight, body mass index (BMI), and waist circumference measures, apart from its impact on blood cholesterol, blood glucose and blood pressure.[6–8] This has become an important question for obesity research to answer,[7–18] although the results across the studies examined showed significant variation, complicating its interpretation.

Therefore, we carried out this meta-analysis, reviewing randomized controlled trials to confirm the relationship between pistachio intake and obesity, to provide a more reliable reference for clinical trials.

2. Methods

2.1. Protocol and registration

A systematic review of randomized clinical trials with meta-analysis was performed. The study protocol was registered in

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The authors have no conflicts of interest to disclose.

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All data generated or analyzed during this study are included in this published article [and its supplementary information files].

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the International Prospective Register of Systematic Reviews (CRD42018104199 available at https://www.crd.york.ac.uk/PROSPERO/). The Medical Ethics Committee of Second Affiliated Hospital of Kunming Medical University informed us that ethical approval was not required. Because the data in the study were retrospective, which were extracted from different studies.

2.2. Eligibility criteria

We included parallel and randomized crossover controlled clinical trials according to the following criteria: original research evaluating pistachio-rich diets; minimum of ten subjects per study; subject ages 30 to 65; trials that reported changes in endpoints (body weight, BMI, waist circumference). Exclusion criteria included no endpoint data; studies spanning <2 weeks; methodologically flawed research; nonoriginal studies, including comment articles, reviews, and letters from researchers; and abstracts not covering all necessary information.

2.3. Information sources and search strategies

We thoroughly searched PubMed, Medline (Ovid), Cochrane Library, Wiley Online Library, Web of Science, and China National Knowledge Infrastructure (CNKI) databases for articles published through July 15, 2018. The search was restricted to randomized controlled diet trials examining the effects of pistachios on body weight measures in adults (30–65 years old). The search was performed without language limitations. The search used free-word retrieval, and the MeSH keywords included "Pistacia vera," "pistachios," "pistachio," "weight," "BMI," "Body Mass Index," and "waist circumference." The search was based on both single and combined keywords. Only clinical trials were included in this study. Additional literature was obtained via manual searches and the retrieval of literature references and related literature reviews.

2.4. Data extraction and quality evaluation

Literature processing software (EndNote X7) was employed to remove repeated publications. Two independent researchers performed a preliminary screening based on the search index. A 3rd-party researcher was included in the discussions and decision-making processes when considering a debatable paper. The basic information extracted included the 1st author's name, the genders of the subjects and their ages and the publication year and country. Relevant endpoint data (including body weight, BMI, and the average change in waist circumference after treatment) were summarized in one form. When different follow-up times were reported by the same group, we chose the longest follow-up time, and when 1 report used different doses of pistachios, we extracted the data from different dose groups. When multiple papers were derived from the same group of patients, the results were pooled and extracted.

Two researchers individually evaluated each article's quality using the Cochrane Collaboration tool for evaluating risk of bias.[19] Each study criterion was evaluated as "Yes," "Unclear," and "No."

2.5. Data analysis

In this meta-analysis, we calculated the average change in all of the parameters from the baseline to the end of the follow-up period between the pistachio diet group and the control diet group. For all studies that only provided the average parameters for both the pistachio and control diet groups, the average change value for the control group was set to 0, and the average change in the pistachio diet group was recorded as the average difference in the report.[20] Standard errors, confidence intervals (CIs), and interquartile ranges (IQRs) were converted into standard deviations for the analysis. The unit of measure chosen for body weight was kilogram, while the unit chosen for waist circumference was centimeter.

Stata Version 12.1 (StataCorp LP, College station, TX) software was used for the meta-analysis. Treatment outcomes were defined as the weighted mean difference and 95% CI of the net change in weight, BMI, and waist circumference. The heterogeneity of studies was evaluated using Cochran Q test, I^2, and the 95% CI. For instance, a Q examination result of $P < .1$ or $I^2 > 50\%$ indicates obvious heterogeneity among the included studies, and a randomized effect model was applied for the meta-analysis. Otherwise, a fixed effect model was used for the analysis. Moreover, in the case of significant heterogeneity, the source of the heterogeneity was investigated using a subgroup analysis (length of intervention [≥12 vs <12 weeks], study design [parallel vs crossover], restriction on fat intake [yes vs no], exercise [yes vs no], pistachio intake [≥50 vs <50 g/d], sample size [≥60 vs <60]) and meta-regression. Publication bias was evaluated using Egger regression tests and funnel plots, with $P < .05$ considered as indicative of significant differences.

3. Results

Out of 516 articles, 22 potentially relevant trials met our criteria after filtering as described earlier. In total, 11 randomized controlled trials published between 2006 and 2017 were included in our research, with 1593 subjects included. Nine articles reported on body weight changes,[8–11,13–17] 8 reported on BMI changes,[7,8,10–13,16,17] and 3 investigated changes in waist circumference.[8,9,11]

3.1. Characteristics of the included studies

Out of the 11 studies included in our research, 4 were carried out in the United States,[13–15,17] 3 took place in Europe,[8,12,16] and 4 were performed in Asia.[7,9–11] Subjects in eight studies had metabolic syndromes,[7–11,13,14,17] including diabetes, abnormal blood cholesterol, and obesity. Subjects in 3 studies were healthy adults[12,15,16] with pregnant woman also included as test subjects.[16] Five studies were crossover controlled trials,[7,8,13–15] and 6 were parallel crossed controlled trials.[9–12,16,17] Regarding intervention strategies, subjects in 3 studies were given pistachios along with a low-fat diet,[10,14,16] subjects in 4 studies were given pistachios in addition to increasing their physical activity, and the assigned pistachio intake was below 50 g/d in 3 studies. Intervention times were shorter than 12 weeks[8,13–15] in 4 studies, and the pistachio diet group and control group had the same calorie intake in 6 studies (see Table S1, Supplemental Content, http://links.lww.com/MD/E753, which illustrates the characteristics of the included studies).[8,9,12–14,17] Quality evaluations are summarized in Table S2 (see Supplemental Content, http://links.lww.com/MD/E754, which illustrates the quality of bias assessment of the included studies according to Cochrane guidelines).

3.2. Relationship between pistachio intake and obesity

We evaluated the effect of pistachio intake on obesity by evaluating changes in 3 parameters: body weight, BMI, and waist circumference (Fig. 1).

Nine studies with 11 treatment arms and a total of 1461 subjects[8–11,13–17] reported body weight changes following pistachio intake. Compared to the control diet group, the pistachio supplementation regimen had no effect on body weight; the net change was 0.22 kg (95% CI: −0.50, 0.07 kg, $P = .141$), and there was no significant heterogeneity ($I^2 = 0.0\%$, $P = .962$).

Eight studies with nine treatment arms and a total of 1375 subjects[7,8,10–13,16,17] reported BMI changes following pistachio

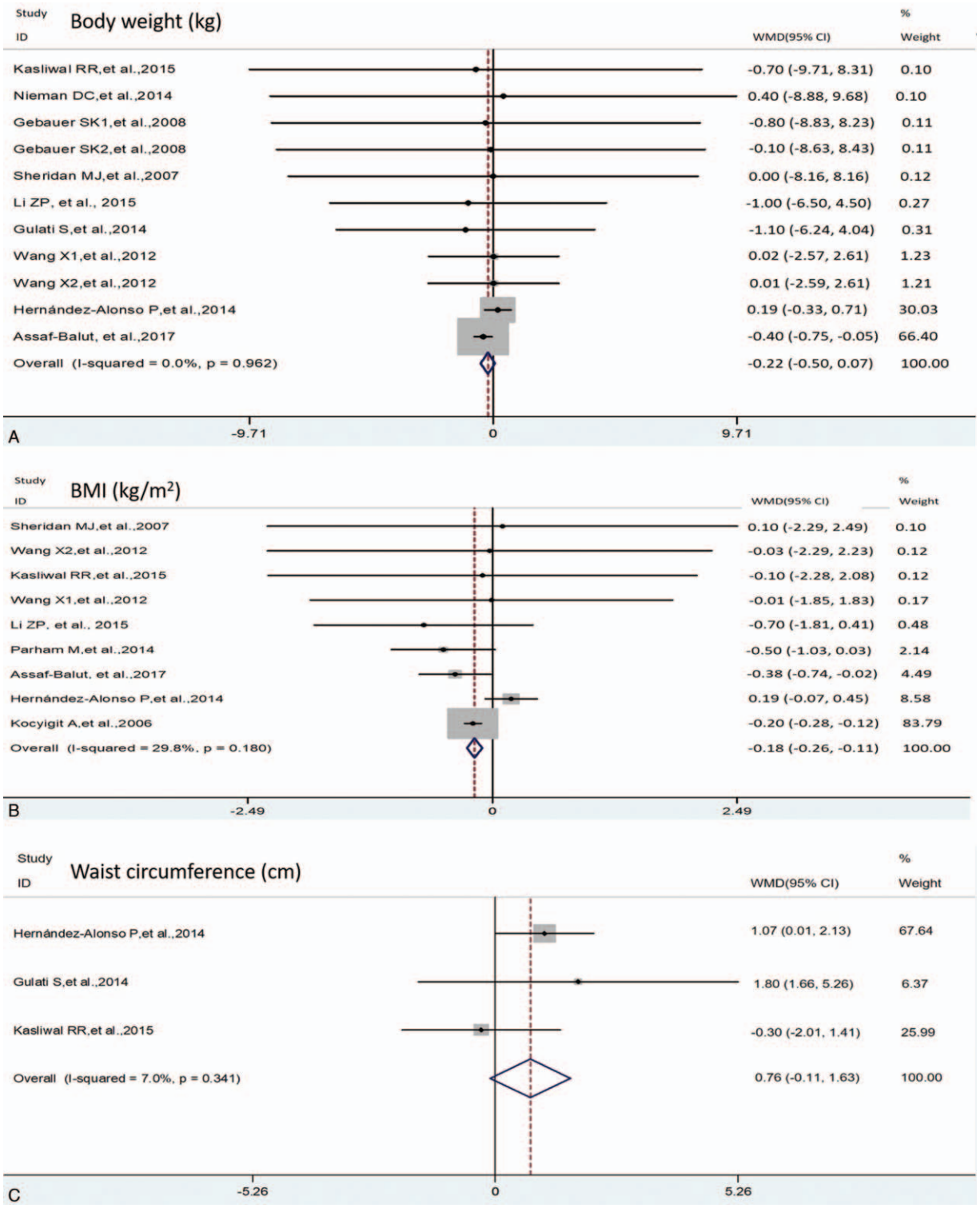

Figure 1. Meta-analysis of the net change in body weight (kg) (A), body mass index (BMI) (in kg/m^2) (B), and waist circumference (cm) (C) associated with nut-enriched diets expressed as the change during the intervention with nut products minus the change during the control diet. WMD = weighted mean difference.

Table 1

Subgroup analyses and meta-regression for weight and BMI.

	Weight, kg					BMI, kg/m^2				
	n	Net change (95% CI)	I^2	P^*	$P^\dagger$	n	Net change (95% CI)	I^2	P^*	$P^\dagger$
Duration										
<12 wks	4	−0.02 (−4.32, 4.28)	0.0	1.000	.952	2	−0.20 (−0.28, −0.12)	0.0	.806	.933
≥12 wks	7	−0.22 (−0.50, 0.07)	0.0	.727	–	7	−0.09 (−0.29, 0.098)	42.0	.111	–
Study design										
Parallel	6	−0.39 (−0.74, −0.05)	0.0	.997	.102	7	−0.22 (−0.30, −0.14)	0.0	.826	.035
Crossover	5	0.19 (−0.33, 0.71)	0.0	1.000	–	2	0.19 (−0.07, 0.45)	0.0	.941	–
Study focus fat										
Restriction	5	−0.39 (−0.73, −0.04)	0.0	.996	.117	3	−0.36 (−0.71, −0.01)	0.0	.890	.570
No restriction	6	0.16 (−0.35, 0.68)	0.0	.994	–	6	−0.17 (−0.25, −0.10)	50.8	.071	–
Physical activity										
Yes	4	−0.40 (−0.75, −0.05)	0.0	.991	.102	2	−0.37 (−0.73, −0.02)	0.0	.804	.534
No	7	−0.16 (−0.33, 0.66)	0.0	1.000	–	7	−0.17 (−0.25, −0.10)	41.2	.117	–
Sample size (n)										
≥60	3	−0.22 (−0.51, 0.07)	42.5	.176	.951	3	−0.08 (−0.27, 0.12)	78.1	.010	.856
<60	8	−0.10 (−1.68, 1.49)	0.0	1.000	–	6	−0.20 (−0.29, −0.12)	0.0	.969	–
Dose of pistachios										
≥50 g/d	8	0.16 (−0.35, 0.66)	0.0	1.000	.113	7	−0.17 (−0.25, −0.10)	41.1	.117	.543
<50 g/d	3	−0.39 (−0.74, 0.04)	0.0	.954	–	2	−0.37 (−0.73, −0.01)	0.0	.764	–

* *P* values were obtained by heterogeneity test.

† *P* values were obtained by using meta-regression analysis.

BMI = body mass index, CI = confidence interval.

intake. The pistachio supplementation regimen significantly decreased BMI, with a net change of −0.18 kg/m^2 (95% CI: −0.26, −0.11 kg/m^2, $P < .001$) and no significant heterogeneity ($I^2 = 29.8\%$, $P = .180$).

Three studies[8,9,11] that included 232 subjects reported a change in waist circumference following pistachio intake. The pistachio supplementation regimen did not significantly change waist circumference; the net change was 0.76 cm (95% CI: −0.11, 1.63 cm, $P = .087$), and there was no significant heterogeneity ($I^2 = 7.0\%$, $P = .340$).

In the subgroup analysis for body weight, a tendency toward intergroup differences was detected in the study design (parallel comparison vs crossover comparison), restricted fat intake (yes vs no) and inclusion of sports (yes vs no), but no significant differences ($P > .05$) were found (Table 1). Subgroup analyses of BMI and pistachio intake tend to show decreased BMI in results from parallel comparisons, while crossover studies tend to show no significant changes; intergroup comparisons showed significant difference ($P = .035$) (Table 1).

Egger examinations of body weight and BMI showed no significant publication bias ($P = .867$ and .987, respectively), and a funnel plot showed no significant asymmetry (Fig. 2). Sensitivity analyses for weight and BMI were performed with step-wise exclusions of each trial to calculate the combined effect, and no significant changes were observed (Fig. 2).

4. Discussion

This is the meta-analysis to systematically summarize the evidence of the effects of pistachio intake on body weight, BMI, and waist circumference. We found that pistachio intake may lower BMI and has no significant effect on body weight.

Some mechanisms can explain the beneficial effects of pistachio consumption. Pistachios contain multiunsaturated fatty acids, which are more easily oxidized than saturated fatty acids and have higher thermogenic effects, therefore decreasing fat accumulation[6]; pistachios have a high fiber content, which could help decrease BMI[21]; pistachios have a high protein content (21%), which decreases food intake by increasing satiety; as with other foods, the chewing process could inhibit hunger sensations; and a small proportion of fat from pistachios is not absorbed, as studies have shown that some fat in pistachio cell walls cannot be absorbed in the intestine.[22]

The effects we observed of pistachio intake on body weight and BMI are slightly different from the findings of a previous meta-analysis.[18] In 1 meta-analysis based on 13 randomized controlled trials studying nut intake and obesity,[18] only 3 trials studied pistachio intake.[12–14] Data regarding subgroup analyses of pistachio intake in relation to body weight came from 2 trials[13,14]; the authors found that pistachio intake had no effect on BMI, which was no consistent with our conclusion. In a previous meta-analysis that included 2 trials studying the effect of pistachio intake on BMI changes, the authors found no correlation.[12,13] In contrast, by including more trials and a larger sample size, our study found that pistachio intake reduced BMI, with no significant between-trial heterogeneity.

In the present study, we pooled data on the effects of pistachio intake on waist circumference and found that pistachio intake had no effect, with no significant between-trial heterogeneity. However, this analysis only included 3 trials with a relatively small sample size. Therefore, this conclusion requires further validation with high-quality trials.

Limitations of this study include the following: We know that to change body weight through pistachio intake, a certain consumption amount, and intervention time is required, though some trials included in our search used <50 g/d and 2 to 3 weeks for the consumption amount and time, respectively. This factor needs to be taken into consideration even though we found no effect of such differences in subgroup and sensitivity analyses. Some interventions were administered in the context of a low-fat diet or lifestyle changes (e.g., exercise). Although the subgroup analysis did not show any effect of a low-fat diet and exercise on

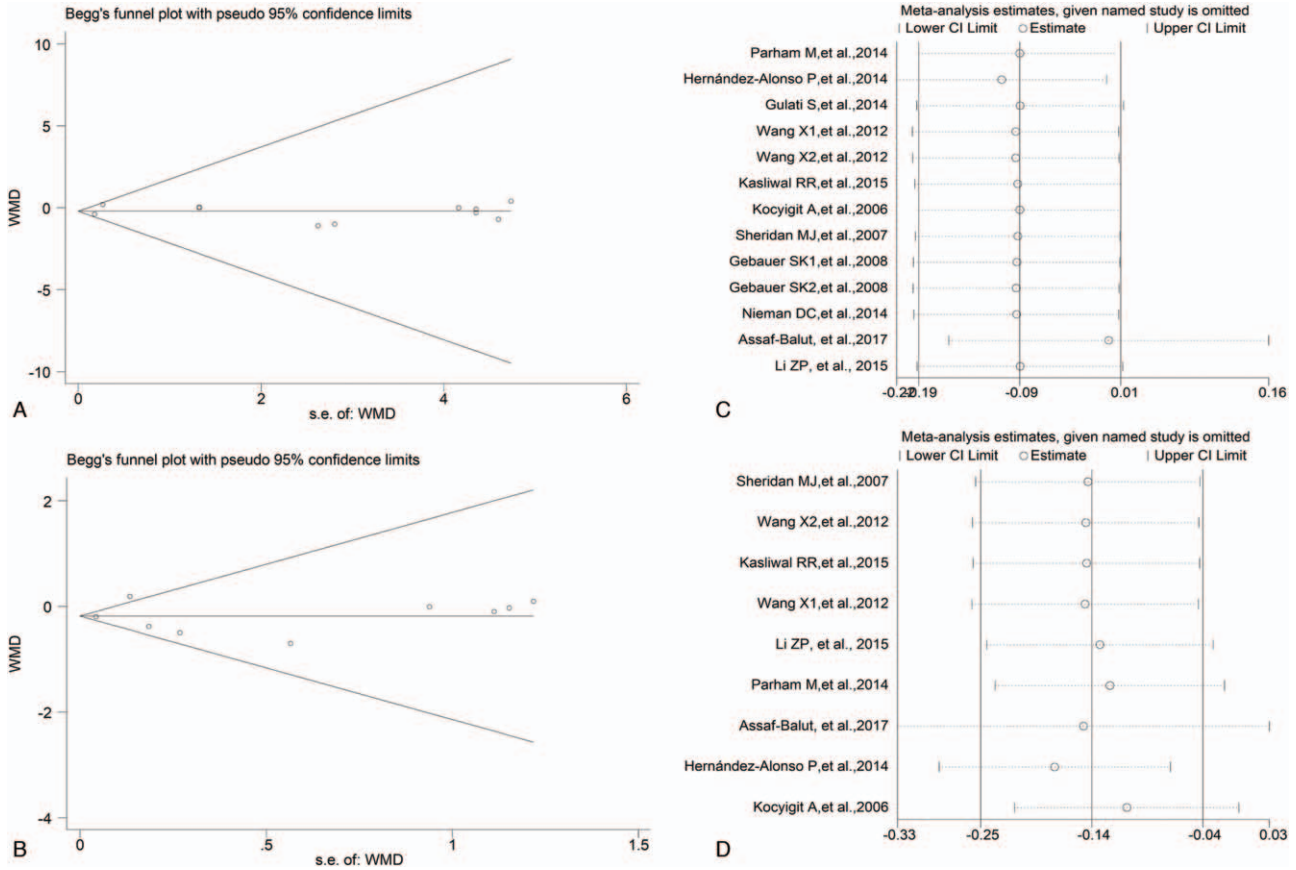

Figure 2. Funnel plot of the estimated publication bias of all studies reporting weight changes (A), body mass index (BMI) changes (B), sensitivity analysis of pooled odds ratios of weight changes (C), and BMI changes (D). CI = confidence interval, s.e. = standard error, WMD = weighted mean difference.

the pooled results, a low-fat diet and lifestyle changes (e.g., exercise) may obscure the beneficial effects of pistachio intake, and as a result, these trials may underestimate the beneficial effects of pistachios. Changes of the body fat content after pistachios intake suggest the positive effects of pistachios on improving adiposity. Unfortunately, little attention has been paid to the changes of body fat content in the included studies. More studies are expected to focus on the changes of fat content after pistachios intakes to make up for this deficiency in future. Most included studies used the changes of net weight and BMI as common indicators to reflect the degree of adiposity. As the influence of body water on the measurement process of these indicators was not excluded, there could be some inaccuracies in this procedure. Finally, most trials included in our study were not double-blinded, which increases study bias.

5. Conclusion

In summary, compared to a controlled dietary intake, an adequate amount of pistachio supplementation lowered BMI without increasing body weight, which supports the view that pistachio consumption is beneficial for human health.

Author contributions

Everyone who contributed significantly to the work has been listed in the author contributions.

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