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# The effect of almond intake on blood pressure: A systematic review and meta-analysis of randomized controlled trials

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ABSTRACT

*Objective:* The present systematic review and meta-analysis aimed determine the efficacy of almond intake on blood pressure (BP).

*Methods:* PubMed, Scopus, ISI Web of Science, Cochrane library and Google Scholar were comprehensively searched to infinity until December 2019. Randomized clinical trials (RCTs) reporting effects of almond intake on aortic and brachial BP were included. Weighted mean differences (WMDs) were pooled using a random-effects model. Standard methods were used for assessment of heterogeneity, sensitivity analysis, and publication bias.

*Results:* A total of 16 RCTs (1128 participants) were included in the meta-analysis. Pooled analysis suggested that almond intake can reduced diastolic BP (DBP) (WMD = -1.30 mmHg; 95 % CI: -2.31,-0.30, p = 0.01, $I^2$ = 0.0 %). However, there was not any impact of almond intake on systolic BP (SBP) (WMD = -0.83 mmHg; 95 % CI: -2.55, 0.89, p = 0.34, $I^2$ = 58.9 %). Subgroup analysis revealed a significant reduction in SBP levels in subjects with lower SBP and lower dose of almonds.

*Conclusion:* We found that almonds might have a considerable favorite effect in BP and especially in DBP, and it could be encouraged as part of a healthy diet; however due to the high calorie content, the intake should be part of healthy diet.

## 1. Introduction

Hypertension, or high blood pressure (BP), is a global public health problem with an increasing incidence worldwide.[1] BP is part of a clinical syndrome resulting from multifactorial etiologies, contributing to the development of cardiovascular diseases (CVDs), including coronary artery disease, angina and myocardial infarction.[1,2] High BP is a well-known risk factor for renal failure, stroke, heart disease, including all-cause mortality and morbidity.[3,4] A small reduction in BP could have a tremendous impact on reducing the burden of CVDs and could possibly have significant public health benefits.[5,6] Thus, the improvement of hypertension in patients, is an essential matter of clinical interest.[7,8]

Dietary factors play a vital role in the development of hypertension.[3,9,10] These factors are crucial, not only because they have been linked to hypertension and CVDs, but also because they can be modified.[11,12] Therefore, diet makes the one of the main goals used in interventions, aiming at the prevention or improvement of hypertension.[13,14]

Recently plant foods, have been recognized as a critical approach against cardiovascular risk factors.[15,16] Among the vast quantity of effective food with beneficial health effects against hypertension, nuts such as almonds have aroused curiosity among scientific community.

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Almonds are a nutrient dense food,[17–19] that could potentially have positive effects on hypertension. Having such good outcomes, there have been arguments whether regular consumption of almonds, as a fatty food, might increase the body weight. As obesity is a major public health problem and a risk factor for hypertension and CVDs,[20,21] several questions would be pondered about advising the consumption of almonds. In this field, a previous meta-analysis with only seven studies was carried out, which had assessed the effects of almonds intake on hypertension.[22] It was reported no difference about systolic BP (SBP) however there was a major drop on the diastolic BP (DBP).

The mechanisms explored by which almonds may have a favorable effect on BP is still not proved yet, however the low content of sodium and high content of mono- and poly-unsaturated fatty acids, vitamins, minerals such as magnesium, potassium,[23] fiber,[24,25] plant sterols/stanols,[26] polyphenolic compounds and antioxidants has been suggested. Also, the modification of microbiota composition,[27] after almond intake could be another possible mechanism, as consuming probiotics and prebiotics could improve BP via various mechanisms.[28,29]

Another two meta-analyses investigated the effect of nuts intake on BP. In the one meta-analysis, that included a large number of studies, they used different nuts including almond, revealed that the tree nut intake did not lower BP.[30] Other meta-analysis reported that the total nut intake can lower SBP and DBP.[31] However it must be noted that nuts contain different types of nutrients and antioxidants[32]; therefore, the exact effect of the almond intake on BP reduction could not be concluded.

So, we aimed to include all randomized, controlled clinical trials (RCTs) to summarize current findings on the effect of almonds intake on BP in adult humans. Results deriving from such investigations can produce the strong evidence, with greater clarity, in the applicability of almonds as a therapeutic resource against hypertension and enable health professionals to make specific recommendations for incorporating almonds in the every healthy diet guidelines.

## 2. Methods

The present systematic review and meta-analysis were performed in accordance with Preferred Reporting Items for Systematic Reviews and Meta- Analysis (PRISMA) statement.[33]

### 2.1. Search strategy

Online medical search engines including PubMed, Scopus, Cochrane library, Web of Knowledge and Google Scholar were searched for relevant articles published from inception until December 2019, without any language limitation. A combination of the two following groups of text or MeSH terms constituted the search strategies: (a) Almond OR Prunus amygdalus OR P. amygdalus OR Prunus dulcis OR P. dulcis and (b) Intervention OR "Intervention Study" OR "Intervention Studies" OR "Controlled trial" OR Randomized OR Randomized OR Random OR Randomly OR Placebo OR "Clinical trial" OR Trial OR "Randomized controlled trial" OR "Randomized clinical trial" OR RCT OR Blinded OR "Double blind" OR "Double blinded" OR Trial OR "Clinical trial" OR Trials OR "Cross-over studies" OR "Cross-over" OR Parallel OR "Parallel study" OR "Parallel trial". The references of the relevant articles and the selected studies were checked to find eligible studies which might have been missed in electronic search. Two authors (E.Gh. and M.M.) conducted the literature search, while in uncertainty was resolved by consensus of third reviewer (A.H.).

### 2.2. Study selection

A two stage screening process, consisting of a title and abstract scan as well as a full-text review, was used to determine the eligibility of articles. Each article was independently reviewed by two investigators (E.Gh. and M.M.). Studies were selected if they met the following inclusion criteria: (a) original RCTs with either parallel or cross-over design; (b) studies conducting on adult subjects ($\geq$18 years); (c) investigating the impact of almond consumption on SBP and/or DBP, and (d) providing required information on outcomes at both baseline and the end of trial (or reported changes in outcomes) for each group (intervention and control). Exclusion of the studies was made in case the duration of intervention was less than one-week, or if almond administration was provided in combination to other active substances. Duplicate publications from the same study were identified and the results with the larger number of cases, were included.

## 3. Data extraction and risk of bias assessment

Two investigators (E.Gh. and M.M.) separately extracted the main information from the selected studies which were as follows: (a) author's last name, (b) year of publication, (c) study design, (e) country, (f) participants' demographic data including: gender, mean age and body mass index (BMI), (g) sample size, (h) duration of the intervention, (i) type of control and intervention, (j) type and amount of the almonds, (k) participants' health condition, and (l) main outcomes. When necessary data were not reported in the papers, we contacted the corresponding authors 2 times via email. Data were cross-checked to minimize potential errors, and disagreements were resolved through discussion with the corresponding author (A.H.).

Two investigators (E.Gh. and M.M.) independently assessed the quality of included studies using the Cochrane risk of bias tool[34] for the following criteria: (a) adequate sequence generation, (b) allocation concealment, (c) blinding of participants, personnel and outcome assessment, (d) incomplete outcome data, (e) selective outcome reporting (reporting bias), and (f) other potential sources of bias. Authors' judgment on each criterion was reported as either "Low", "High" or "Unclear" risk of bias, in accordance with Cochrane Handbook. Any disagreement in data extraction and risk of bias assessment was settled by discussion.

## 4. Statistical analysis

Statistical analysis was performed by using STATA software version 12 (STATA Corp, College Station, TX, USA). The outcomes were collected as mean change and standard deviation (SD) from all eligible studies to calculate pooled effect size. When the mean change was not provided, weighted mean difference (WMD) was computed by subtracting baseline values from measures at the end of intervention. SD of the change was also calculated by a formula suggested by Follmann et al.[35] To compensate between study heterogeneity random-effect or fixed-effect model were used based on percent of heterogeneity. The heterogeneity between the studies was examined by the I-squared ($I^2$) index. Subgroup analysis was conducted based on baseline SBP, trial duration, participants' age, almond dose, health status and BMI in order to explore the source of heterogeneity. Random-effects meta-regression was used to evaluate the impact of potential moderators on the calculated net changes. Sensitivity analysis was also conducted, by removing each study at time, to assess whether overall effect size was reached by individual study. Publication bias tests performed base on Begg's test and visual inspection of the funnel plots. P-Values $< 0.05$ were considered statistically significant.

## 5. Results

### 5.1. Study selection

Initially, we identified 2983 records from mentioned databases, of which we, we removed 1115 duplicates. Then, two of the investigators screened the remaining articles based on title and abstract. Forty 40 papers were eligible to full-text review. Among these 21 studies[36–58] were excluded because they did not examine BP and 3 articles were

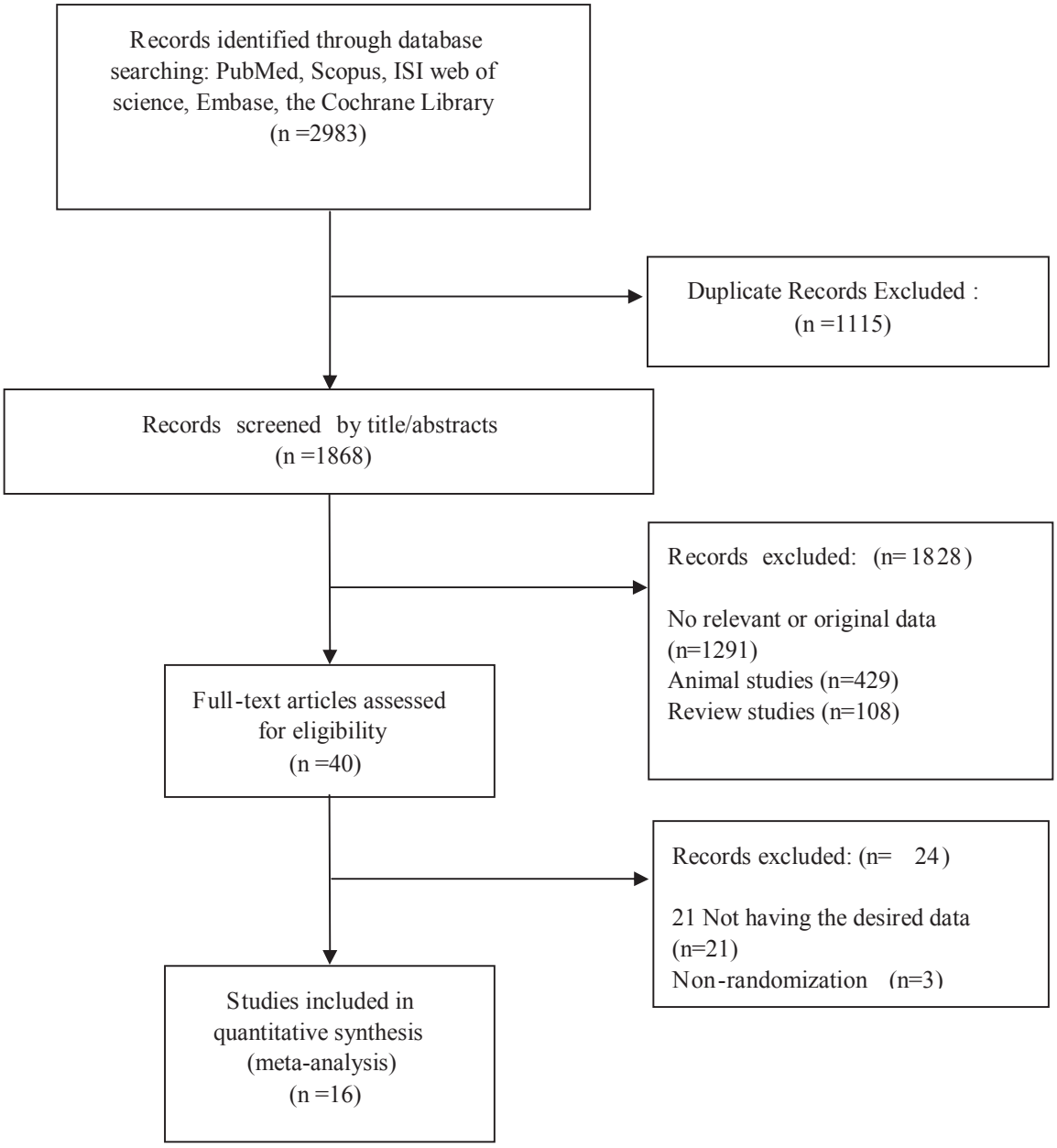


**Fig. 1.** PRISMA flow diagram of study selection process.

excluded due to non-randomization.[59–61] Finally, 16 studies were included to the present meta-analysis. Flowchart of study selection is illustrated in Fig. 1.

### 5.2. Characteristics of the included studies

The characteristics of the eligible studies are presented in Table 1. These studies performed in the USA,[32,62–69] Taiwan,[70] Spain,[71] Pakistan,[72] New Zealand,[52] Iran,[73] Canada,[74] and Brazil[75] and were published between 2002 and 2018. Studies' duration ranged from 3 to 77.4 weeks. The almonds' dosage varied between 10 and 73 g/d in the eligible studies. Also, the design of 5 of the included study was crossover[52,68,70,71,74] and the rest were parallel.,[32,62–6769,72,73,75] Only 3 trials were conducted on women[52,73,75] and rest trials performed on both sexes.,[32,62–7274] The sample size ranged from 12[67] to 123[63] and in total 1128 participants were included, of which 685 individuals were allocated to the intervention group and 443 individuals to the control group. The mean age of the volunteers ranged from 32 to 87 years and the mean baseline BMI varied from 18.5 to 39.0 kg/m$^2$. These trials conducted on healthy,[67,69] overweight and obese adults,[32,63,66,68,73,75] with hyperlipidemia[74] and hypercholesterolemia,[62,71] and in patients with coronary artery disease,[72] pre diabetes[62,64] and type 2 diabetes mellitus.[52,70,75]

### 5.3. Quality assessment

Random allocation of participants was performed in all of the included studies.[32,52,62–75] However, 6 trials described the method of allocation concealment.[32,62,64,68,69,72] All of the trials had high risk of bias regarding the blinding of the participants and personnel. Regarding the outcome assessors, there was unclear risk of bias. Included trials had low risk of bias based on incomplete outcome data and selective outcome reporting. Details of risk of bias assessment are described in Table 2.

**Table 1**
Characteristic of included studies in meta-analysis.

| Author | Publication Year | Country | Study Design | Participant | Sex | Trial Duration (Week) | Means Age | | Means BMI | | Intervention | | Control | Sample Size | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | IG | CG | IG | CG | Kind of almond | dose of almond (g) | | IG | CG |
| D J A Jenkins | 2002 | Canada | crossover | Healthy hyperlipidemic men and postmenopausal women | M/F:15/12 | 4.28 | Group1: 64 Group2: 64 | | Group1: 25.7 Group2: 25.7 | | whole almonds | Group1: 73 ± 3 Group2: 36.5 ± 3 | whole-wheat muffins | Group1: 27 Group2: 27 | |
| M A Wien | 2003 | USA | parallel | overweight and obese adults | M/F:28/37 | 24 | 53 | 57 | 39 | 37 | unsalted almonds | 84 | self-selected complex carbohydrates (CHO-LCD) | 32 | 33 |
| M Wien | 2010 | USA | parallel | individuals with prediabetes | M/F:17/48 | 16 | 53 | 54 | 29.3 | 29 | raw or dry roasted almonds | 56 | nut-free | 32 | 33 |
| N R T Damasceno | 2011 | Spain | crossover | hypercholesterolemic patients | M/F:9/9 | 4 | 56 | 56 | 25.7 | 25.7 | Almonds | 50−75 | Virgin olive oil | 18 | 18 |
| G D Foster | 2012 | USA | parallel | Overweight and obese individuals | M/F:11/112 | 77.14 | 47 | 46.7 | 33.9 | 34 | Almond | 56 | Hypo caloric nut-free diet (NFD) | 61 | 62 |
| SY Tan | 2013 | USA | parallel | Participants with increased risk for type 2 diabetes | Group1:M/F:16/39 Group2 M/F:20/35 Group3 M/F:17/36 Group4 M/F:16/39 | 4 | 18−60 | 18−60 | 18.5–24.9 | 18.5–24.9 | almonds | Group1: 43 Group2: 43 Group3: 43 Group4: 43 | snack or no almonds | Group1: 28 Group2: 28 Group3: 26 Group4: 28 | 27 |
| K Richmond | 2013 | New Zealand | crossover | Postmenopausal Women with Type 2 Diabetes | F:22 | 3 | 62 | 62 | 29.16 | 29.24 | Almond | 30 | sunflower kernels | 22 | 22 |
| K L Sweazea | 2014 | USA | parallel | individuals with T2D | M/F:9/11 | 12 | 25−75 | 25−75 | NR | NR | Almonds | 43 | customary diet | 10 | 10 |
| Z Abzarfard | 2014 | Iran | parallel | overweight and obese females | F:100 | 12.85 | 42.36 | 42.94 | 29.91 | 29.37 | raw almond | 50 | balanced hypo caloric nut-free diet (NFD) | 50 | 50 |
| H Jamshed | 2015 | Pakistan | parallel | CAD patients | M/F: NR | 12 | 32–86 | 32–86 | NR | NR | Group1: American almonds Group2: Pakistani almonds | Group1: 10 Group2: 10 | no-intervention | Group1: 41 Group2: 38 | 34 |
| J Dhillon | 2016 | USA | parallel | Overweight or Obese Adults | M/F:15/35 | 12 | 33.6 | 34.9 | 30.3 | 30.6 | dry roasted almonds | 15 % energy | nut-free diet (NFD) | 23 | 27 |
| C M Chen | 2017 | Taiwan | crossover | patients with better controlled type 2 diabetes | M/F:13/20 | 12 | 54.9 | 54.9 | 25.6 | 25.3 | almonds | 60 | NCEP step II diet | 33 | 33 |
| Y Lee | 2017 | USA | crossover | Overweight and Obese Individuals | Group1:M/F:18/13 Group2:M/F:18/13 Group3:M/F:18/13 | 4 | Group1: 46.3 Group2: 46.3 Group3: 46.3 | 46.3 | Group1: 29.6 Group2: 29.6 Group3: 29.6 | 29.6 | raw almonds | 42.5 | Group1: cocoa and dark chocolate Group2: chocolate diet Group3: no treatment foods (average American diet) | Group1: 31 Group2: 31 Group3: 31 | 31 |
| C S Johnston | 2017 | USA | parallel | sedentary older adults | M/F:3/9 | 8 | 55.5 | 52.7 | 28 | 25.6 | almonds | 70 | isocaloric control butter spread | 6 | 6 |

(*continued on next page*)

**Table 1** (*continued*)

| Author | Publication Year | Country | Study Design | Participant | Sex | Trial Duration (Week) | Means Age | | Means BMI | | Intervention | | Control | Sample Size | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | IG | CG | IG | CG | Kind of almond | dose of almond (g) | | IG | CG |
| R G M Souza | 2018 | Brazil | parallel | overweight and obese women | F:46 | 8 | NR | NR | 32.54 | 33.34 | roasted baru almonds | 20 | baru almond-free diet (BAFD) | 24 | 22 |
| J Dhillon | 2018 | USA | parallel | Young Adults | M/F:32/41 | 8 | 18–19 | 18–19 | 25.6 | 25.3 | Almond | 56.7 | Cracker | 38 | 35 |

Abbreviations: IG, intervention group; CG, control group; DB, double-blinded; SB, single-blinded; PC, placebo-controlled; CO, controlled; RA, randomized; NR, not reported; F, Female; M, Male; NR, not reported.

## 6. Meta-analysis results

### 6.1. Effect of almonds intake on SBP

The overall result of our meta-analysis of 23 arms (685 cases and 443 controls) with random-effect model, demonstrated that there was no significant decrease in SBP (WMD = -0.83 mmHg; 95 % CI: -2.55, 0.89, p = 0.34) with considerable heterogeneity between studies (p < 0.001, $I^2$ = 58.9 %) (Fig. 2). To find any source of heterogeneity, we performed subgroup analyses based on baseline SBP (< 120/ > 120 mmHg), trial duration (< 6/≥6 weeks), participant's age (≥50/ < 50 years), almonds dose (≥45/ < 45 g/d), health (healthy/ unhealthy) and participant's BMI (normal/overweight/obese). Heterogeneity was insignificant in subjects with baseline SBP greater than 120 mmHg during a short term intervention, aging older than 50 years, having a low dose of almond and in unhealthy ones with normal BMI. This also indicated a significant lowering effect of almond intake on SBP in subjects with lower SBP and low dose of almonds (Table 3).

### 6.2. Effect of almonds intake on DBP

DBP was checked through fixed-effect model due to percent of heterogeneity (0%). The effect of the almond intake on DBP was evaluated in 23 arms of clinical trials (685 cases and 443 control subjects) and the pooled mean difference revealed a significant reduction in DBP (WMD = -1.30 mmHg; 95 % CI: -2.31,-0.30, p = 0.01) with insignificant between-study heterogeneity (p = 0.67, $I^2$ = 0.0 %) (Fig. 3).

### 6.3. Sensitivity analysis

We conducted sensitive analysis to find the effect of each single study on the overall effect size. We found no significant impact of any individual trial on the overall effect size of SBP. However, the sensitivity analysis for DBP, appeared an influenced by elimination of studies performed by Abzarfard et al.[73] (WMD = -0.51 mmHg; 95 % CI: -1.45,0.43) and Dhillon et al. (2016)[66] (WMD = -0.77 mmHg; 95 % CI: -1.70,0.15).

### 6.4. Publication bias

Publication bias tests performed base on Begg's test and visual inspection of the funnel plots. The results of analysis demonstrated that, there was no evidence of publication bias for studies examining the effect on almond intake in both SBP (p = 0.89) and DBP (p = 0.79) (Fig. 4).

## 7. Discussion

The present meta-analysis, with 16 included studies, indicated that almond intake significantly decreased DBP. Inconsistently, almonds could not significantly decrease SBP, although, a there was a significant drop on the SBP seen in subjects with lower SBP and lower dose of almonds.

SBP usually reflects the total peripheral resistance and/or large artery stiffness, while DBP reflects the peripheral vascular resistance.[76] On the other hand, cardiovascular responses including SBP and DBP, in the interventions might be different, although, this has been expected as SBP and DBP are correlated in most subjects.[76] Thus, in our study, the favorable effects on DBP provided by almonds, could be related to the reduced peripheral vascular resistance. There are mixed findings regarding sub-grouped items. This divergence might depend on the differences in the different dietary compliance and calorie intake,[32] dietary sodium, sex, smoking, visceral adiposity, insulin resistance, inflammation and different physiological response to intervention, which can alter the BP.[77] Moreover, different timing of almonds intake,[78] mastication and bioavailability factors,[79] discrepancy in the

**Table 2**
Quality assessment of included studies based on Cochrane guidelines.

| Study | Random Sequence Generation | Allocation concealment | Blinding of participants personnel | Blinding of outcome assessors | Incomplete outcome data | Selective outcome reporting | Other sources of bias |
|---|---|---|---|---|---|---|---|
| D J A Jenkins | L | U | H | U | L | L | L |
| M A Wien | L | L | H | U | L | L | L |
| M Wien | L | L | H | U | L | L | L |
| N R T Damasceno | L | U | H | U | L | L | L |
| G D Foster | L | U | H | U | L | L | L |
| SY Tan | L | L | H | U | L | L | L |
| K Richmond | L | U | H | U | L | L | L |
| K L Sweazea | L | U | H | U | L | L | L |
| Z Abzarfard | L | U | H | U | L | L | L |
| H Jamshed | L | L | H | U | L | L | L |
| J Dhillon | L | U | H | U | L | L | L |
| C M Chen | L | U | H | U | L | L | L |
| Y Lee | L | L | H | U | L | L | L |
| C S Johnston | L | U | H | U | L | L | L |
| R G M Souza | L | U | H | U | L | L | L |
| J Dhillon | L | L | H | U | L | L | L |

U, unclear risk of bias; L, low risk of bias; H, high risk of bias.

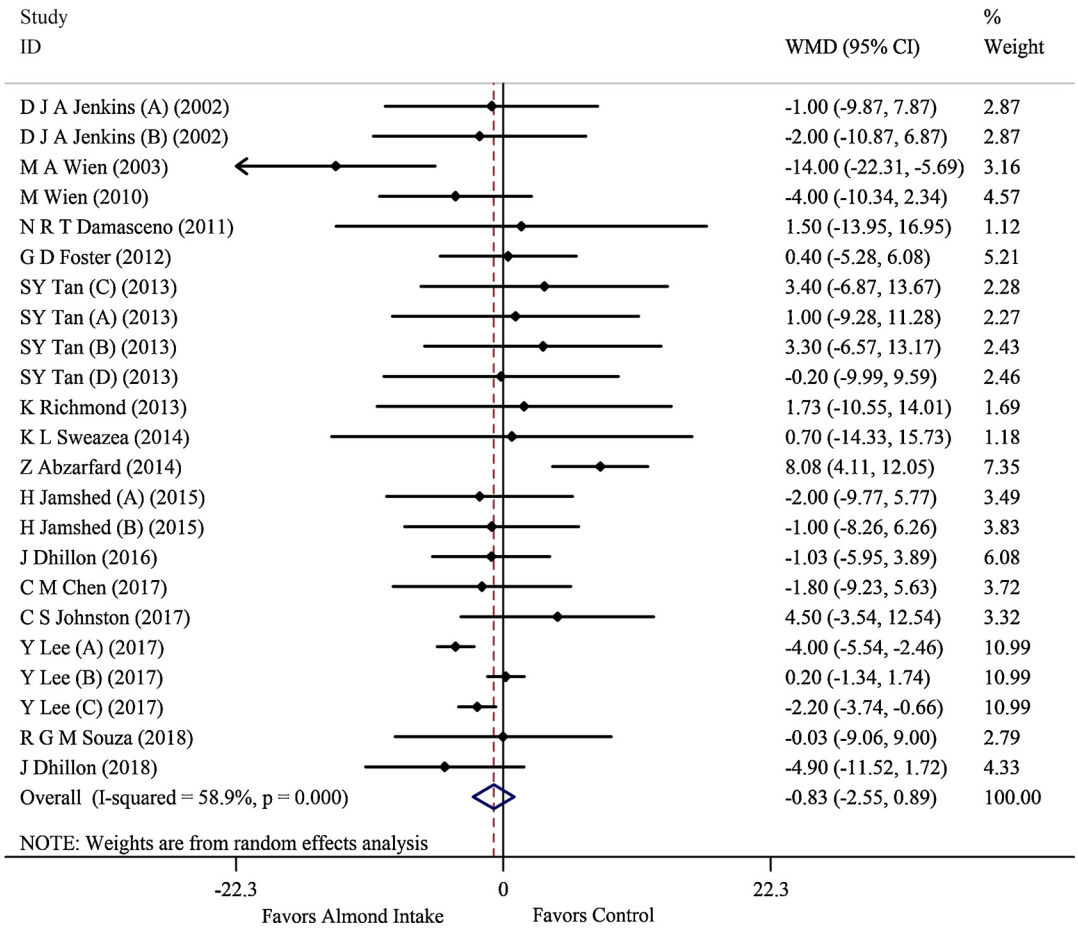


**Fig. 2.** Forest plot of the effects of almond intake on SBP.

context of almonds varieties,[80] geographical and botanical almonds' origin,[81] harvest time and storage conditions[82] and processing[83] which greatly influence the biological activity of almonds, could affect the results. In addition, the diversified used methods for BP measurements may contribute to the different clinical response.[84]

In this field, a previous meta-analysis was carried out, which assessed the effects of almond intake on hypertension.[22] The previous study included only 7 studies, while here we have included 16 studies with 23 arms; it could prove more robust findings. In mentioned study, it was reported no difference about SBP, but DBP was significantly decreased after almond consumption. Also, other two meta-analyses examined the health benefits of nuts intake, including almonds. The one of them revealed that the tree nut intake did not lower BP.[30] In the meta-analysis it was reported that the nut intake can reduce SBP and DBP.[31] As, nuts contain different types of nutrients and antioxidants,[32] in mentioned studies, it is not possible to estimate the true effect of almonds on BP reduction.

The mechanisms by which almonds may have a favorable

**Table 3**
Subgroup analyses to assess the effect of almond intake on SBP.

| | No of trials | WMD (95 %CI) | P within group | P heterogeneity | $I^2$ |
|---|---|---|---|---|---|
| Subgroup analyses of almond intake on SBP. | | | | | |
| Overall effect | 23 | −0.67 (-2.25, 0.89) | 0.39 | < 0.001 | 69.7% |
| Baseline SBP (mmHg) | | | | | |
| < 120 | 5 | −2.01 (-2.63, -1.40) | < **0.001** | < 0.001 | 86.7% |
| > 120 | 18 | 0.77 (-0.81, 2.36) | 0.33 | 0.01 | 46.9% |
| Trial duration (week) | | | | | |
| < 6 | 11 | −1.84 (-2.45, -1.23) | < **0.001** | < 0.001 | 72.2% |
| ≥6 | 12 | 0.14 (-1.70, 1.98) | 0.88 | 0.001 | 66.2% |
| Participant's age | | | | | |
| ≥50 | 8 | −2.50 (-5.38, 0.36) | 0.08 | 0.12 | 38.7% |
| < 50 | 7 | −1.74 (-2.35, -1.14) | < **0.001** | < 0.001 | 89.1% |
| Almond Dose (g) | | | | | |
| ≥45 | 9 | 0.64 (-1.52, 2.80) | 0.56 | < 0.001 | 74.8% |
| < 45 | 13 | −1.83 (-2.43, -1.23) | < **0.001** | < 0.001 | 66.7% |
| Health status | | | | | |
| Heathy | 12 | −1.76 (-2.36, -1.17) | < **0.001** | < 0.001 | 83.3% |
| unhealthy | 11 | −0.02 (-2.25, 2.21) | 0.92 | 0.92 | 0.0 % |
| Obesity status | | | | | |
| Normal | 4 | 1.82 (-1.41, 5.05) | 0.27 | 0.82 | 0.0 % |
| Over weight | 12 | −1.75 (-2.35, -1.15) | < **0.001** | < 0.001 | 81.0% |
| Obese | 4 | −2.35 (-5.53, 0.82) | 0.14 | 0.02 | 66.6% |

Abbreviations: CI, confidence interval; SBP, systolic blood pressure, DBP, diastolic blood pressure; WMD, weighted mean differences.

alternation in BP levels are diverse, due to the large number of almonds' compounds. They are low in sodium and rich in unique nutrients and bioactive component like mono- and poly-unsaturated fatty acids, vitamins, minerals such as magnesium, potassium, calcium, fiber, plant sterols/stanols, and polyphenolic compounds and antioxidants. All these compositional properties confer almonds as the potential to beneficially influence BP.[25,84] Another accepted explanation for BP reduction associated with almonds consumption is the increased dietary fiber intake. Fiber in almonds, with a range of abilities to increases fecal bulk, minimizes the transit time in the intestine, as well as the calories intake and body weight, followed by drop in the satiety, that could cause the improvements in BP.[24,25,85] Almonds are also abundant in L-

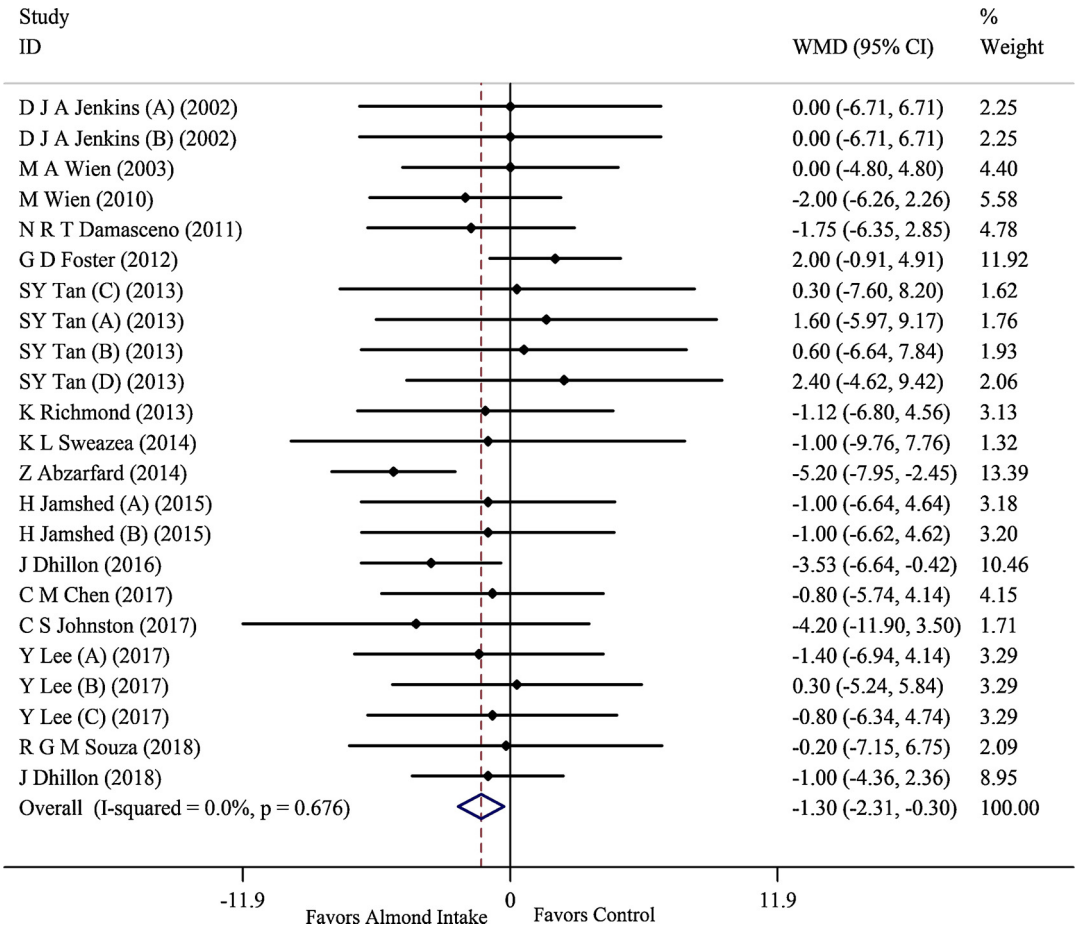


**Fig. 3.** Forest plot of the effects of almond intake on DBP.

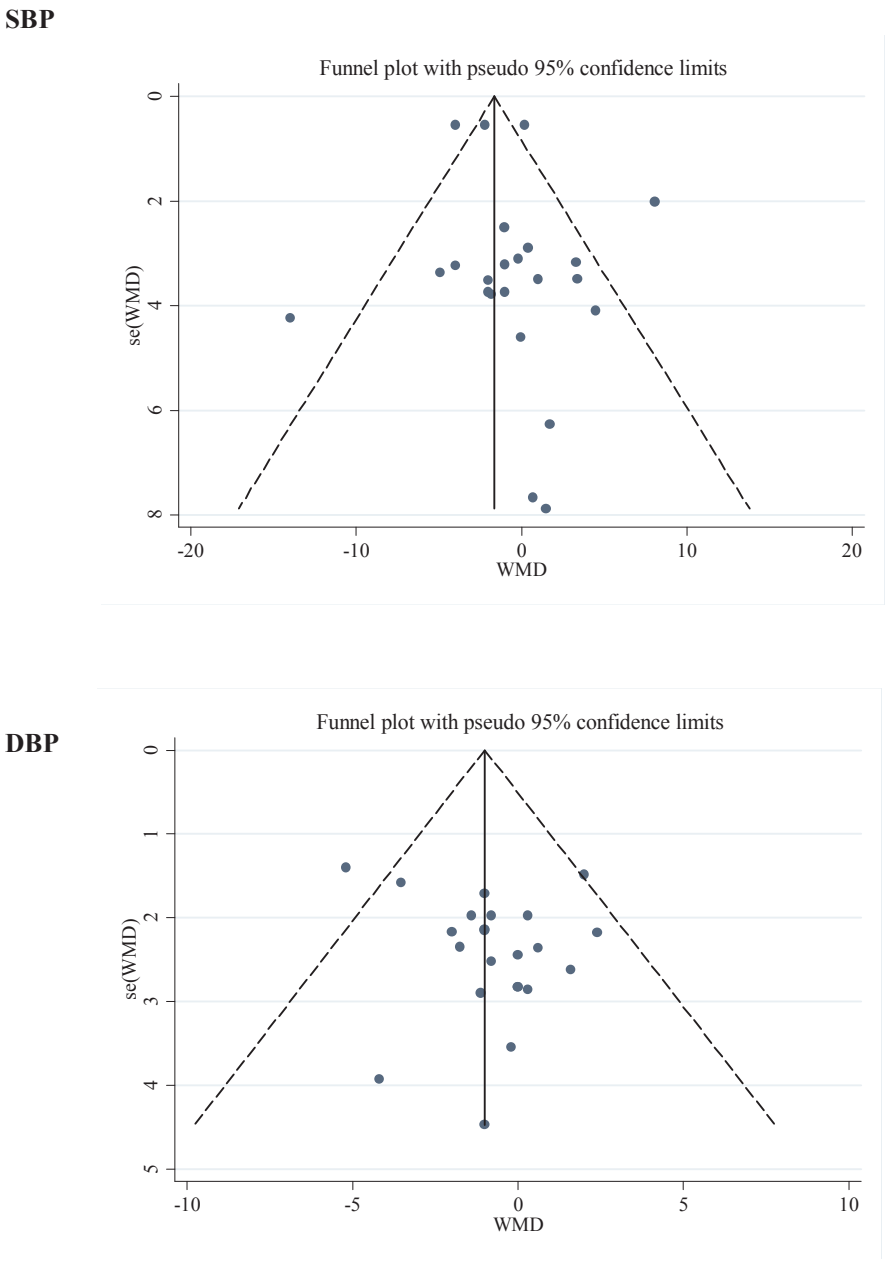


**Fig. 4.** Funnel plot of the effects of almond intake on SBP and DBP.

arginine, which is a rate-limiting substrate for the production of endothelial nitric oxide, a messenger with muscle relaxation effects which can be an important mechanism for the blood pressure reduction.[86–89] The modification of microbiota composition and induction the number of potentially beneficial bacteria, bifidobacteria and Eubacterium rectale,[27] by almonds is another possible mechanism for improvement the BP. It was suggested that consuming probiotics and prebiotics could improve BP via various mechanisms.[28,29]

It is crucial to mention that nuts are an energy-dense food and might cause a debate about any adverse effects on health. However scientific evidence did not support associations between nut consumption and weight gain.[90] On the contrast, nuts, have been associated with lower risk of obesity, probably due to satiety and fullness which may potentially bring low the consumption of unhealthy snacks.[91,92] However due to the high calorie being as a part of healthy diet and substituted in the diet could be a more reasonable.

### 7.1. Side effects

Some of the studies had minor adverse effects. The most well-known adverse effect of consumption of almonds is allergic reaction.[93,94] Furthermore, increased almond consumption, as a nut, might be believed to cause weight gain.[93] Due to the high oxalate content in nuts, such as almonds, could be a risk factor contributing for kidney stone formation in some individuals.[94]

### 7.2. Study strengths and limitations

The present meta-analysis had several limitations. The effects of main confounding variables including, genetic background, lifestyle modification, medications, dietary patterns and almonds' varieties on the efficacy of almonds remained unclear.

The main strength of the current study was the subgroup analysis and assessment of the baseline SBP, trial duration, participant's age, almonds dose, health and obesity status on the overall effect sizes.

Running an analysis depending on between-group's mean changes, also made our work more accurate than within-group changes leading to find greater effect sizes. Reducing any biases in the review process, was another strength, as we performed a comprehensive search of the literature and by conducting and reporting the review adhering to PRISMA guidelines.

### 7.3. Implications for practice

The evidence from this meta-analysis suggest that almonds may have beneficial effects on the BP. Based on the current scientific knowledge, it could be encouraged to include them, as part of a healthy diet in order to reduce the risk of hypertension.[66] It should be noted that results cannot be generalized to those with other health problems, such as liver disease and cancer that were not included in this analysis.

### 7.4. Implications for research

Future large, long duration, high-quality trials preferentially using ambulatory BP monitoring, the best standard for BP measurements,[84,95] should be designed to ensure low risk of bias and meet the current reporting standards for clinical trials. Daily dosing regimen ideally could be tailored to the individual to improve the evidence in this field. As we mentioned previously, other factors that can affect the results, such as different dietary compliance of subjects, lifestyle factors, production process, storage, and geographical and botanical almonds' origin, that need to be considered when designing a study. Another critical point, is that the beneficial effects of almonds and the cost-benefits to improve BP should be assessed.

## 8. Conclusion

We found that almonds might have a considerable favorite effect in BP and especially in DBP, and it could be encouraged as part of a healthy diet; however due to the high calorie content, the intake should be part of healthy diet.

## Conflict of interest

The authors declare no conflict of interest.

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