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The effect of dietary approaches to stop hypertension (DASH diet) on overweight or obese patients with hypertension: An updated systematic review and meta-analysis with GRADE-assessed approach

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Abstract

Background: This systematic review and meta-analysis evaluated the effects of the DASH diet on blood pressure in overweight or obese adults with hypertension.

Methods: A comprehensive literature search was conducted in online databases, including SCOPUS, Medline, and Web of Science, up to 1 February 2024.

Results: This meta-analysis incorporated a comprehensive collection of 21 studies. The findings indicated that the DASH diet had a notable impact on decreasing systolic blood pressure (SBP), as demonstrated by a weighted mean difference (WMD) of -4.75 mmHg (95% confidence interval (CI): -6.23, -3.28; P-Value < 0.001). Additionally, the DASH diet was found to have a significant influence on reducing diastolic blood pressure (DBP) [WMD of -4.17 mmHg (95% CI: -4.34, -4.00; P-Value < 0.001)]. Subgroup analysis revealed that the results remained significant when age was ≥50 years, in females, among ethnic groups from Europe, Asia, and America, as well as in groups classified as obese individuals.

Conclusion: The DASH diet has conclusive effects on blood pressure, especially in obese individuals. The DASH diet could be considered an important dietary strategy for the management of hypertension in obese and overweight adults.

Article Type: Systematic Review and Meta Analysis

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Highlights

What is current knowledge?

- Hypertension is highly prevalent among overweight and obese individuals and represents a major global cardiovascular risk factor.
- Lifestyle modification, particularly dietary intervention, is recommended as a first-line non-pharmacological strategy for blood pressure control.
- The DASH diet is widely recognized for lowering blood pressure and improving cardiometabolic risk factors in the general hypertensive population.
- However, evidence specifically evaluating the effectiveness of the DASH diet in overweight or obese hypertensive adults remains limited and inconsistent.

What is new here?

- This updated systematic review and meta-analysis provides comprehensive evidence from 21 clinical trials including 4,395 participants.
- The DASH diet significantly reduces both systolic and diastolic blood pressure in overweight and obese patients with hypertension.
- Greater blood pressure reduction was observed in obese individuals, older adults (≥50 years), and interventions lasting longer than 12 weeks.
- Using a GRADE-assessed approach, this study strengthens the evidence supporting the DASH diet as an effective dietary strategy specifically for hypertensive patients with excess body weight.

Introduction

Obesity is defined as the excessive and unhealthy accumulation of body fat, which is determined by calculating the body mass index (BMI) (1-4). The prevalence of overweight and obesity has increased across all age groups, irrespective of ethnicity or socioeconomic status (3,4). By 2030, the World Obesity Federation estimates that one billion people, including 1 in 5 women and 1 in 7 men, will be obese (5). Obesity increases the risk of chronic diseases such as non-alcoholic fatty liver disease (NAFLD), chronic renal disease, hypercholesterolemia, and cardiovascular disease (2-4,6,7).

Current definitions of hypertension include SBP of 130 mm Hg or higher and/or DBP of 80 mm Hg or greater (8). Although the diagnosis and classification of hypertension have evolved over time, most guidelines agree that individuals with persistent BP readings of 140/90 mm Hg or greater should receive treatment to reduce levels to 130/80 mm Hg (8). Obesity and hypertension are closely linked because excess abdominal fat alters the endocrine and immunological systems, increasing the likelihood of insulin resistance, diabetes, hypertension, and cardiovascular disease (9-12). The global prevalence of hypertension is estimated to affect around one billion people, making it one of the leading risk factors for mortality worldwide (13). Obesity is a major risk factor for hypertension in both adults and children, independent of race, ethnicity, or gender (11,14-16). Epidemiological research suggests that obesity may account for 65-78% of the risk associated with primary hypertension (10,17). At any stage of hypertension, patient management involves both lifestyle modifications and medication (18,19). However, studies indicate that non-pharmacological therapy should be strongly recommended as the

primary treatment for stage 1 hypertension, alongside pharmacological therapy (19). For individuals diagnosed with hypertension, engaging in healthful behaviors such as maintaining a normal BMI and waist circumference, being physically active for at least four days per week, avoiding smoking, consuming alcohol in moderation, managing sodium intake, and adhering to the Dietary Approaches to Stop Hypertension (DASH) diet has been shown to provide significant health benefits (19-21). The DASH diet is the most widely used dietary intervention for blood pressure management (22). It emphasizes whole grains, fruits, vegetables, low-fat dairy products, lean meats, fish, poultry, nuts, seeds, and legumes, with minimal fats and oils and moderate sodium restriction (22-24). This diet is low in saturated and trans fats and high in antioxidants, minerals, fiber, and nitrates (24). When combined with a low-sodium intake, it has been shown to be an effective method for lowering blood pressure (23). In addition, it effectively reduces other cardiovascular risk factors such as blood glucose, blood lipids, body weight, and waist circumference (22,25-27).

This meta-analysis aims to provide a comprehensive review of the effects of the DASH diet in hypertensive individuals who are overweight or obese. By examining various studies and their outcomes, this study seeks to clarify the effectiveness of this dietary approach in this specific population and contribute to the ongoing discussion on non-pharmacological interventions for hypertension management.

Methods

We used the PRISMA guideline, which includes evidence-based items for reporting systematic reviews and meta-analyses, to ensure that our work was transparent, comprehensive, and consistent with best practices in the field (28). Our systematic review and meta-analysis were registered in PROSPERO, a reputable database specifically designed for registering systematic reviews. The study was assigned the registration number CRD42023472719.

Search strategy

To identify all relevant clinical trials up to September 2023, we searched online databases including SCOPUS ([http://www.scopus.com] (http://www.scopus.com)), Medline ([http://www.ncbi.nlm.nih.gov/PubMed] (http://www.ncbi.nlm.nih.gov/PubMed)), and Web of Science ([https://clarivate.com/scientific-and-academic-research/] (https://clarivate.com/scientific-and-academic-research/)). In addition, hand searches were conducted in Google Scholar ([https://scholar.google.com/] (https://scholar.google.com/)) and Cochrane ([https://www.cochrane.org/] (https://www.cochrane.org/)) to identify additional relevant studies. To ensure a comprehensive search and minimize the risk of publication bias, grey literature and unpublished materials were also included in the search strategy. These sources encompassed conference abstracts, dissertations/theses, and records from clinical trial registries. The following search syntax was used in the mentioned databases:

((("Dietary Approaches to Stop Hypertension"[Title/Abstract] OR DASH[Title/Abstract] OR dash[Title/Abstract] OR "dash diet"[Title/Abstract] OR "dietary pattern"[Title/Abstract] OR "DASH diet"[Title/Abstract] OR "dietary approaches"[Title/Abstract]) AND (obese[Title/Abstract] OR overweight[Title/Abstract] OR "weight status"[Title/Abstract] OR BMI[Title/Abstract] OR "body mass index"[Title/Abstract] OR obesity[Title/Abstract] OR weight[Title/Abstract] OR adipose[Title/Abstract] OR body-mass-index[Title/Abstract] OR "abdominal obesity"[Title/Abstract] OR "Body Weight"[Title/Abstract] OR BW[Title/Abstract] OR over-weight[Title/Abstract] OR "elevated BMI"[Title/Abstract] OR "hip circumference"[Title/Abstract] OR HC[Title/Abstract] OR "waist circumference"[Title/Abstract] OR WC[Title/Abstract] OR "waist-hip ratio"[Title/Abstract] OR WHR[Title/Abstract] OR "body fat percentage"[Title/Abstract] OR BFP[Title/Abstract] OR "Central obesity"[Title/Abstract] OR Overnutrition[Title/Abstract] OR "excess weight"[Title/Abstract] OR adiposity[Title/Abstract] OR "body fat"[Title/Abstract] OR "fat mass"[Title/Abstract] OR "high trunk fat mass"[Title/Abstract] OR "anthropometric measurements"[Title/Abstract] OR "general obesity"[Title/Abstract] OR "Overall obesity"[Title/Abstract] OR fat[Title/Abstract] OR "abdominal body fat"[Title/Abstract] OR "Overall body fat"[Title/Abstract] OR "visceral obesity"[Title/Abstract] OR "visceral fat"[Title/Abstract])) AND ("Blood pressure"[Title/Abstract] OR Hypertension[Title/Abstract] OR "Systolic Pressure"[Title/Abstract] OR "Diastolic Pressure"[Title/Abstract] OR "Pulse Pressure"[Title/Abstract] OR "high blood pressure"[Title/Abstract] OR "High blood pressure"[Title/Abstract] OR HBP[Title/Abstract] OR hyperten[Title/Abstract] OR hypertensive[Title/Abstract] OR "raised blood pressure"[Title/Abstract] OR "elevated blood pressure"[Title/Abstract] OR SBP[Title/Abstract] OR DBP[Title/Abstract] OR "isolated systolic blood pressure"[Title/Abstract] OR "high BP"[Title/Abstract] OR BP[Title/Abstract] OR "raised BP"[Title/Abstract] OR "elevated BP"[Title/Abstract] OR HTN[Title/Abstract])).

All retrieved studies were imported into EndNote software (Version X9 for Windows; Thomson Reuters, Philadelphia, PA, USA) for screening. Duplicate records were removed. Unpublished sources or grey literature, such as conference abstracts, theses, and patents, were excluded if the required data were unavailable or could not be extracted. In addition, a manual search of the reference lists of studies identified through the search strategy, as well as relevant previous reviews, was conducted to identify any additional studies that may have been missed during the screening process. No restrictions were applied regarding language or date of publication. The steps involved in the literature search are illustrated in Figure 1.

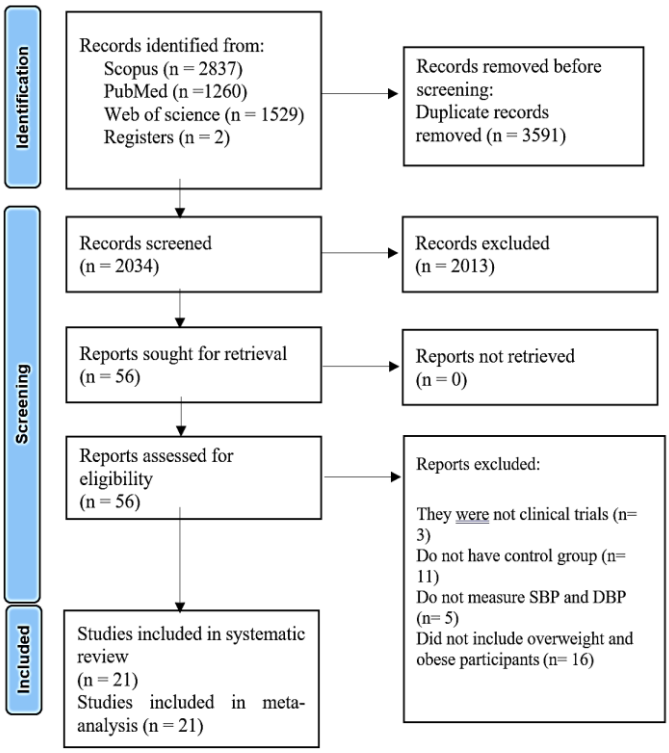

Figure 1. Flow diagram of the study

Criteria

Inclusion criteria

We included clinical trials that fulfilled the following criteria: (A) randomized clinical trials with either parallel or crossover designs; (B) participants were overweight or obese (BMI ≥ 25); (C) Participants had abnormal BP (BP ≥ 120/80); (D) the intervention group was compared with a placebo or control group; (E) the intervention group received the DASH diet, while the control group received usual care, a habitual diet, general dietary advice, or an alternative dietary regimen; (F) data were reported as mean and standard deviation (SD) or could be converted to this format.

Exclusion criteria

Studies were excluded if they met the following criteria: (A) Non-clinical trials, (B) Duplicate publications, (C) Animal, in vitro, observational, or review studies, (D) Studies involving pregnant women, (E) Studies involving children, (F) Studies in which participants did not receive the DASH diet, and (G) Studies that did not assess or report BP outcomes.

Data extraction

Four independent researchers (JR, KF, NM, GY) extracted the required data using a standardized data collection form. Relevant studies were included in the present analysis after reviewing their titles and abstracts. Two additional researchers (MV, HM) resolved any discrepancies in the data extraction process. The following information was extracted: First author, publication year, mean age (Years), gender, study design, sample size, type of intervention, duration of intervention (Weeks), health status, BMI (kg/m²), measurement tools, and changes in SBP and DBP (mmHg). The mean changes and standard deviations of BP measurements were calculated for both the intervention and control groups. BP data reported in different units were converted to the most frequently used unit.

Risk of bias assessment

To assess the risk of bias for each study included in the current meta-analysis, we used the Cochrane quality assessment tool (29,30). This tool consists of seven domains: Random sequence generation, allocation concealment, reporting bias, performance bias, detection bias, attrition bias, and other potential sources of bias. A score of "high risk" was assigned to a domain if the study had methodological concerns that could have affected its findings. A score of "low risk" was assigned if no methodological limitations were identified for that domain. If the available information was insufficient to determine the potential impact, a score of "unclear risk" was assigned. Studies that met the criteria for "low risk" across all domains were considered to have an overall low risk of bias. Two reviewers (HM and MV) independently assessed the risk of bias (Table 1).

Statistical analysis

The mean changes in BP measurements and their corresponding SDs were used to calculate the overall effect sizes for both the intervention and control groups. Mean changes in BP were calculated by analyzing the differences observed during the intervention period, even when they were not explicitly reported. When mean changes and their SDs were not directly provided, the mean change was calculated as the difference between baseline and endpoint values. The SD of the change was estimated using standard formulas, assuming a conservative correlation coefficient between baseline and follow-up measurements, as recommended in the Cochrane Handbook (31,32).

For studies reporting the standard error of the mean (SEM), the SD was calculated by multiplying the SEM by the square root of the sample size, as follows: $SD = SEM \times \sqrt{n}$. All blood pressure outcomes were reported in mmHg; therefore, no additional unit conversions were required. When studies reported continuous variables as median and interquartile range (IQR), these values were converted to mean and standard deviation (SD) using established statistical methods described by Wan et al. and Luo et al. (31,32).

A random-effects model was applied to account for between-study variability and to provide a more accurate estimate of the overall effect sizes. The I^2 statistic and Cochrane's Q test were used to assess heterogeneity. Significant heterogeneity was considered present if the I^2 value was > 50% or P-Value < 0.05 (33). To explore potential sources of heterogeneity, subgroup analyses were conducted based on predefined variables, including gender (Female, Both), baseline SBP (<140 mmHg, ≥140 mmHg), baseline DBP (<85 mmHg, ≥85 mmHg), age (<50 years, ≥50 years), baseline BMI (Overweight (25-29.9 Kg/m²), obese (>30 Kg/m²)), ethnicity (Asia, Africa, America, Australia, Europe), and trial duration (>12 weeks, ≤12 weeks) (Table 2).

All subgroup analyses were predefined and conducted on an exploratory basis to identify potential sources of heterogeneity. Effect sizes (WMDs with 95% CIs) were reported for all subgroups, and no formal adjustment for multiple comparisons was applied; therefore, subgroup findings should be interpreted with caution. A sensitivity analysis was performed to determine whether the overall effect size was dependent on any single study. The formal tests developed by Begg and Egger were used to assess the possibility of publication bias. Stata version 17.0 was used to perform the meta-analysis. The statistical significance level was set at 0.05.

Certainty assessment

The GRADE Working Group approach was used to grade the overall certainty of evidence across studies according to established guidelines (34). Based on the relevant assessment criteria, the certainty of evidence was categorized into four levels: High, moderate, low, and very low. Two authors (MV and HM) independently conducted the GRADE assessment and then reached a consensus to produce a single final evaluation (Table 3).

Table 1. Quality assessment

Studies	Random sequence generation	Allocation concealment	Selective reporting	Other sources of bias	Blinding (Participants and personnel)	Blinding (Outcome assessment)	Incomplete outcome data	General risk of bias
Hinderliter 2021	L	L	L	H	L	L	L	Low
Said 2020	H	U	L	L	U	U	L	Low
Soric 2019	L	U	L	H	H	H	L	High
Kucharska 2018	L	H	L	H	H	H	L	High
Juraschek 2018	L	H	H	L	H	U	H	High
Choi 2015	L	L	L	L	U	U	L	Low
Hinderliter 2013	L	U	L	H	L	L	L	Low
Lima 2013	L	L	H	L	U	U	L	Low
Lin 2012	L	L	H	L	H	H	H	High
Pratheret 2011	L	U	L	L	H	U	L	Low
Smith 2010	L	H	H	H	L	U	L	High
Blumenthal 2010	L	L	L	L	U	L	L	Low
Malloy-mcfall 2010	L	U	L	H	H	U	L	High
Chen 2010	L	U	L	L	L	U	L	Low
Al-Solaiman 2009	L	U	L	L	H	U	L	Low
Nowson 2009	L	U	L	L	H	U	L	Low
Elmer 2006	L	L	L	L	H	L	L	Low
Burke 2005	L	L	H	H	U	U	L	Moderate
Azadbakht 2005	L	L	L	L	H	L	L	Low
Conlin 2003	L	L	L	H	L	L	L	Low
Moore 2001	L	U	H	H	H	U	H	High

L: Low risk; U: Unclear; H: High risk
General Low risk < 2 High risk
General Moderate risk = 2 High risk
General High risk >2 High risk

Table 2. Subgroup analyses of DASH diet on overweight or obese patients with hypertension

Variables	No.	WMD (95%CI)	P-Value	Heterogeneity		
				P heterogeneity	I2	P between sub-groups
Subgroup analyses of DASH diet on SBP						
Overall effect	40	-4.75 (-6.23, -3.28)	< 0.001	< 0.001	94.6%	-
Baseline SBP (mmHg) < 140 ≥ 140	 25 15	 -3.43 (-3.99, -2.93) -8.45 (-8.70, -8.20)	 < 0.001 < 0.001	 < 0.001 < 0.001	 86.3% 94.9%	< 0.001
Trial duration (Week) ≤ 12 > 12	 19 21	 -3.68 (-4.17, -3.20) -8.62 (-8.88, -8.36)	 < 0.001 < 0.001	 < 0.001 < 0.001	 90% 91.5%	< 0.001
Age < 50 ≥ 50	 14 26	 -3.28 (-4.03, -2.54) -4.02 (-4.51, -3.53)	 < 0.001 < 0.001	 < 0.001 < 0.001	 91.1% 79.3%	< 0.001
Sex Both sexes Female	 34 6	 -7.85 (-8.08, -7.62) 2.13 (0.86, 3.41)	 < 0.001 0.001	 < 0.001 0.001	 93.1% 72.8%	< 0.001
Baseline BMI (kg/m2) Overweight (25-29.9) Obese (>30)	 12 28	 -2.32 (-3.14, -1.50) -4.29 (-4.76, -3.81)	 < 0.001 < 0.001	 < 0.001 < 0.001	 91.3% 78.5%	< 0.001
Ethnic America Europe Asia Africa Australia	 32 2 3 1 2	 -7.83 (-8.07, -7.59) -3.61 (-4.84, -2.38) -7.73 (-10.64, 4.82) -4.15 (-6.60, -1.69) -2.21 (-3.77, -0.65)	 < 0.001 < 0.001 < 0.001 0.001 0.005	 < 0.001 0.256 0.04 - 0.631	 95% 22.6% 68.8% - 0.0%	< 0.001
Subgroup analyses of DASH diet on DBP						
Overall effect	38	-3.17 (-3.96, -2.39)	< 0.001	< 0.001	93%	-
Baseline DBP (mmHg) <85 ≥85	 12 26	 -5.46 (-5.70, -5.22) -2.93 (-3.17, -2.69)	 < 0.001 < 0.001	 < 0.001 < 0.001	 93.9% 81.4%	< 0.001
Trial duration (Week) ≤12 >12	 17 21	 -2.98 (-3.22, -2.74) -5.34 (-5.58, -5.10)	 < 0.001 < 0.001	 < 0.001 < 0.001	 86% 91.2%	< 0.001
Age <50 ≥50	 13 25	 -3.07 (-3.36, -2.77) -2.64 (-2.96, -2.32)	 < 0.001 < 0.001	 < 0.001 < 0.001	 81.5% 79.3%	< 0.001
Sex Both sexes Female	 32 6	 -4.65 (-4.86, -4.45) -3.05 (-3.36, -2.74)	 < 0.001 < 0.001	 < 0.001 < 0.001	 92.2% 91.2%	< 0.001
Baseline BMI (kg/m2) Overweight (25-29.9) Obese (>30)	 12 26	 -3.07 (-3.30, -2.72) -2.69 (-3.02, -2.35)	 < 0.001 < 0.001	 < 0.001 < 0.001	 83.7% 78.4%	< 0.001
Ethnic America Europe Asia Australia Africa	 31 2 3 2 0	 -4.19 (-4.37, -4.02) -4.33 (-5.10, -3.56) -5.22 (-8.04, -2.40) -1.69 (-3.07, -0.31) -	 < 0.001 < 0.001 < 0.001 0.016 -	 < 0.001 0.654 0.965 0.581 -	 94.1% 0.0% 0.0% 0.0% -	0.010

Abbreviations: CI, Confidence Interval; WMD, Weighted Mean Differences; SBP, Systolic Blood Pressure; DBP, Diastolic Blood Pressure.

Table 3. GRADE profile of DASH diet on overweight or obese patients with hypertension

Quality assessment						Summary of findings		Quality of evidence
Outcomes	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Number of intervention/Control	WMD (95%CI)	
SBP	Low	Very serious limitations [a]	No serious limitations	No serious limitations	Serious limitations	2239/2156	-4.75 (-6.23, -3.28)	⊕⊕◯◯ Low
DBP	Low	Very serious limitations [b]	No serious limitations	No serious limitations	Serious limitations	2193/2110	-4.17 (-4.34, -4.00)	⊕⊕◯◯ Low

[a] The test for heterogeneity is significant, and the I2 is high, 94.5%
[b] The test for heterogeneity is significant, and the I2 is high, 92.8%

Results

Study selection

A total of 5,628 articles were identified from three databases (Scopus, PubMed, and Web of Science) and registries. The initial search yielded 2,837 records from Scopus, 1,260 from PubMed, 1,529 from Web of Science, and 2 from registries. These totals correspond to the initial records shown in Figure 1. After removing 3,591 duplicate records, 2,034 unique articles remained for further screening.

Following title and abstract screening, 2,013 studies that did not meet the inclusion criteria were excluded. Of these, 1,879 had titles and abstracts irrelevant to the research topic, 55 were conducted on animal subjects, and 23 were review articles. As a result, 56 studies were considered eligible for full-text review.

After full-text assessment, three studies were excluded due to the absence of a clinical trial design. Additionally, five studies did not report SBP or DBP outcomes, 11 studies lacked an appropriate control group, and 16 studies did not include overweight or obese participants. Ultimately, 21 studies met all specified inclusion criteria and were included in the meta-analysis. Figure 1 presents the PRISMA flow diagram outlining the study selection process.

Study characteristics

Overall, 21 studies involving 4,395 participants (2,239 cases and 2,156 controls) were included in the analysis (35-55). The included articles were published between 2001 (49) and 2021 (21). The intervention duration ranged from 4 (44) to 48 (21) weeks, and the sample size of the included studies ranged from 20 (41,48) to 542 (42) participants. The mean age of participants ranged from 38.5 (48) to 73 (40) years, and BMI ranged from 25.6 (40) to 35.72 (52).

All studies were parallel RCTs, except for three that used a crossover design (35,41,44). The studies were conducted in various countries, including the USA (21,35,37,39,41-44,47-49,51,53), Egypt (52), Croatia (54), Poland (45), South Korea (40), Brazil (46), Australia (38,50), and Iran (36). Baseline SBP ranged from 122.1 (51) to 154 (44) mmHg, and baseline DBP ranged from 71.2 (51) to 95 (41) mmHg. The characteristics of the included studies are summarized in Table 4.

Quality assessment

The quality of the included studies was evaluated using the Cochrane risk-of-bias tool (Table 1), which comprises seven domains: Random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other potential sources of bias. Each domain was assessed individually and categorized as low risk, high risk, or unclear risk.

Based on this assessment, 13 studies (21,35-37,39-43,46,50-52) were classified as having a low risk of bias, one study (38) was categorized as having an intermediate risk of bias, and seven studies (44,45,47-49,53,54) were considered to have a high risk of bias.

Effect of the DASH diet on SBP

A total of 21 studies, encompassing 40 effect sizes, were included in this analysis. These studies involved a combined sample size of 4,395 participants, with 2,239 individuals in the intervention (Case) groups and 2,156 in the control groups. The primary aim of these studies was to examine the effect of the DASH diet on SBP. The results demonstrated that the DASH diet had a statistically significant effect on reducing SBP, with a weighted mean difference (WMD) of -4.75 mmHg (95% confidence interval [CI]: -6.23, -3.28; P-Value < 0.001), as shown in Figure 2A.

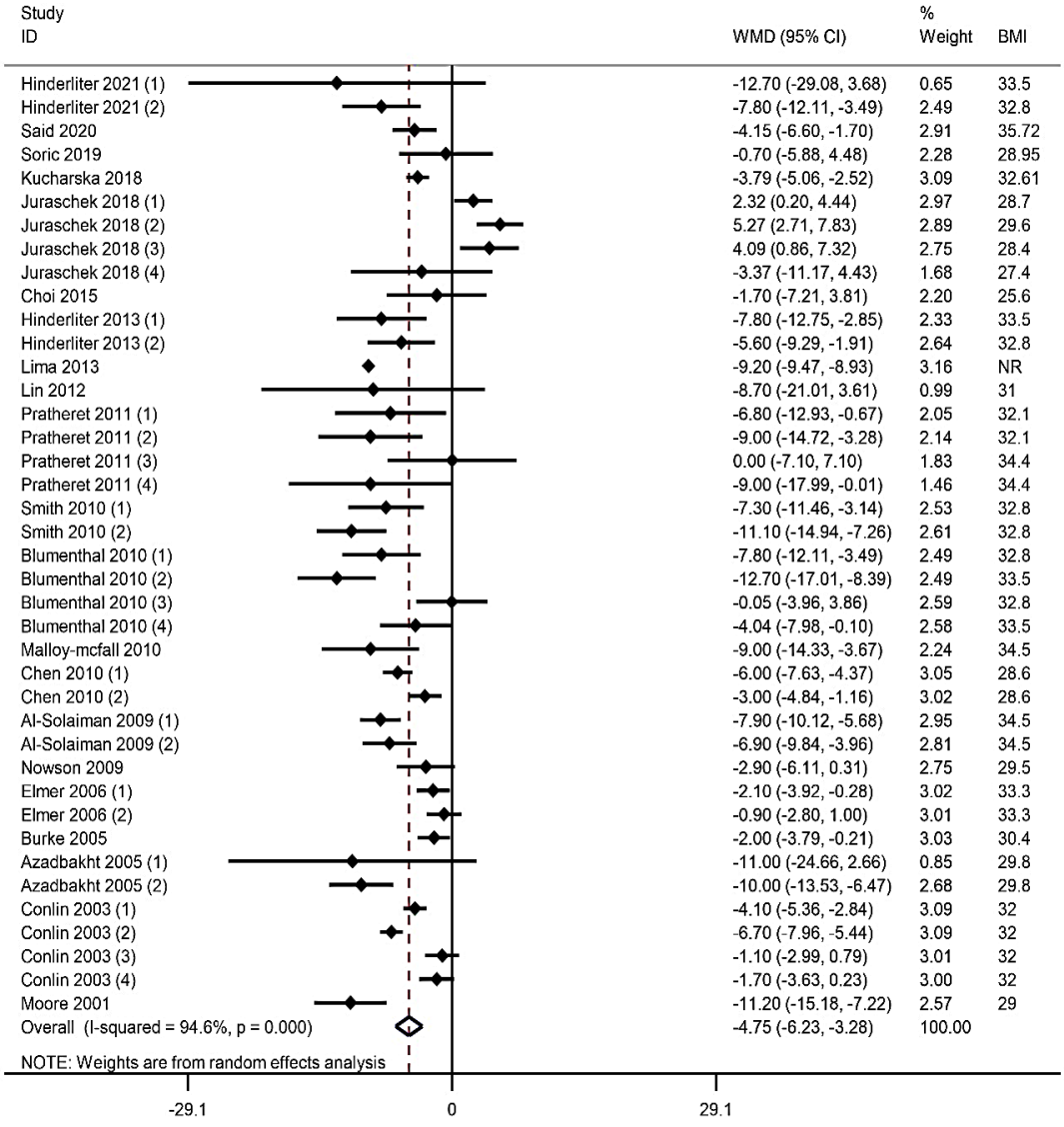

Figure 2A. Forest plot of DASH diet effect on SBP [WMD: -4.75 mmHg; 95% CI: -6.23, -3.28; P-Value < 0.001].

Nevertheless, a substantial level of heterogeneity was observed among the studies (I^2 = 94.6%, P-Value < 0.001). Subgroup analyses indicated that several factors, including gender (Female, Both), baseline SBP (<140 mmHg, ≥140 mmHg), age (<50 years, ≥50 years), baseline BMI (Overweight (25-29.9 kg/m^2), obese (>30 kg/m^2)), ethnicity (Asia, Africa, America, Australia, Europe), and trial duration (>12 weeks, ≤12 weeks), contributed to the observed heterogeneity.

The subgroup analysis showed that the effects of the DASH diet on SBP remained statistically significant, and heterogeneity was reduced in subgroups with age ≥50 years (I^2 = 79.3%), female participants (I^2 = 72.8%), and among ethnic groups from Europe (I^2 = 22.6%), Asia (I^2 = 68.8%), and Australia (I^2 = 0.0%), as well as in groups classified as obese (I^2 = 78.5%). In addition, studies with intervention durations longer than 12 weeks demonstrated the greatest reduction in SBP (-8.62 mmHg [−8.88, −8.36]), and participants with baseline SBP ≥140 mmHg experienced a large and significant reduction (-8.45 mmHg [−8.70, −8.20]) (Table 2).

Effect of the DASH diet on DBP

A total of 19 studies, encompassing 38 effect sizes, were included in this analysis. These studies involved a combined sample size of 4,303 participants, with 2,193 individuals in the intervention (Case) groups and 2,110 in the control groups. The primary objective of these studies was to examine the effect of the DASH diet on DBP. The results demonstrated that the DASH diet had a statistically significant effect on reducing DBP, with a weighted mean difference (WMD) of -3.17 mmHg (95% confidence interval [CI]: -3.96, -2.39; P-Value < 0.001), as shown in Figure 2B.

Nevertheless, substantial heterogeneity was observed among the studies (I^2 = 93%). Subgroup analyses indicated that several factors, including gender (Female, Both), baseline DBP (<85 mmHg, ≥85 mmHg), age (<50 years, ≥50 years), baseline BMI (Overweight (25-29.9 kg/m^2), obese (>30 kg/m^2)), ethnicity (Asia, Africa, America, Australia, Europe), and trial duration (>12 weeks, ≤12 weeks), contributed to the observed heterogeneity.

The subgroup analysis showed that the effects of the DASH diet on DBP remained statistically significant, and heterogeneity was reduced in subgroups with participants from Europe (I^2 = 0.0%), Asia (I^2 = 0.0%), and Australia (I^2 = 0.0%), as well as in those with baseline DBP ≥85 mmHg (I^2 = 81.4%). In addition, participants with baseline DBP <85 mmHg experienced the greatest reduction in DBP (-5.46 mmHg [−5.70, −5.22]), and studies with intervention durations longer than 12 weeks demonstrated a significant and substantial reduction in DBP (-5.34 mmHg [−5.58, −5.10]) (Table 2).

Sensitivity analysis and publication bias

Sensitivity analysis indicated that the overall effects of the DASH diet on SBP and DBP were not driven by any single study. Visual inspection of the funnel plots suggested the presence of publication bias in studies evaluating the effect of the DASH diet on SBP (Egger: <0.001; Begg: 0.003) and DBP (Egger: 0.01; Begg: 0.037) (Figures 3A and 3B).

Meta-regression analysis

Meta-regression was performed to examine the potential linear association between the duration of the intervention and the absolute changes in blood pressure. The results of the meta-regression analysis showed no significant linear relationship between intervention duration and changes in SBP (P for linearity = 0.64) or DBP (P for linearity = 0.09) (Figures 4A and 4B).

Grading of evidence

The certainty of the evidence was evaluated using the GRADE approach (Table 3).

Studies examining the impact of the DASH diet on systolic blood pressure (SBP) and diastolic blood pressure (DBP) were considered to be of low quality due to substantial heterogeneity among studies and the presence of publication bias.

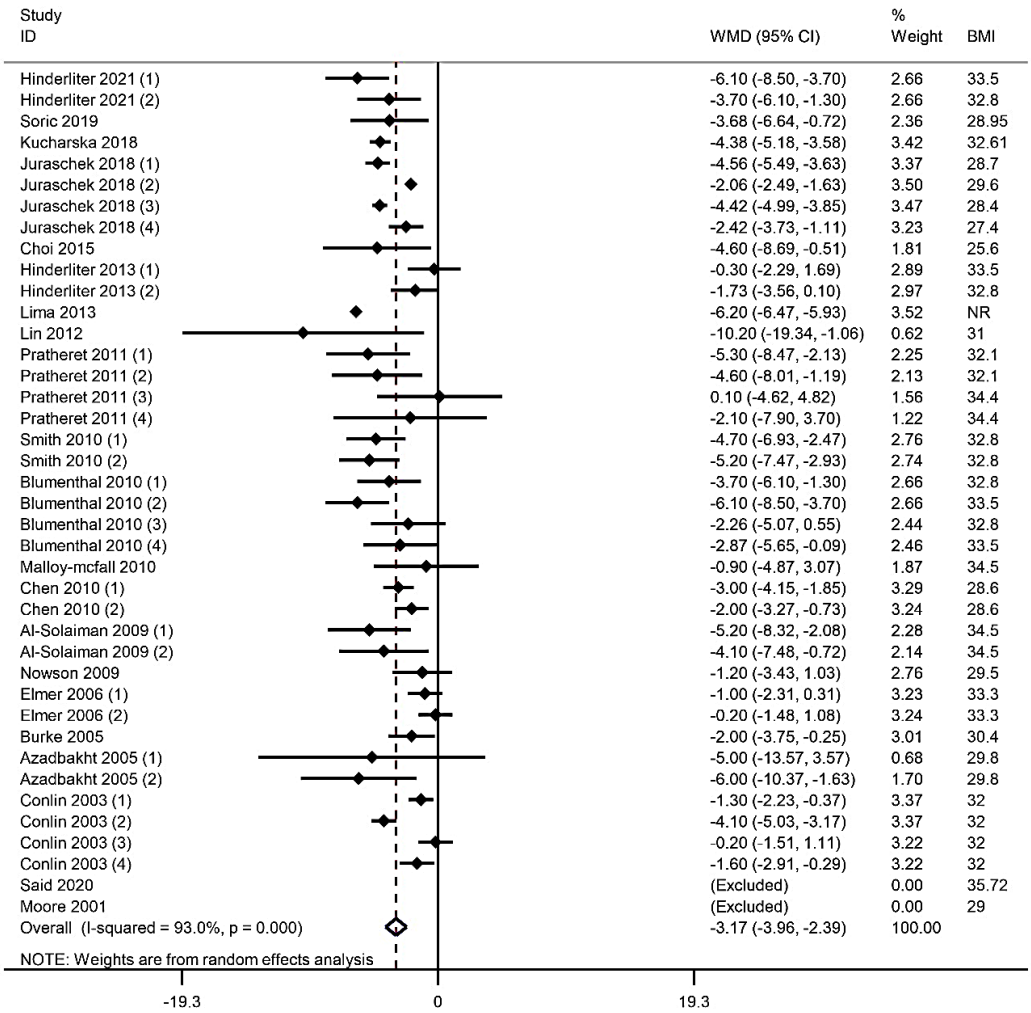

Figure 2B. Forest plot of DASH diet effect on DBP [WMD: -3.17 mmHg; 95% CI: -3.96; P-Value < 0.001]

Table 4. Characteristic of included studies in meta-analysis

Pratheret 2011	Lin 2012	Lima 2013	Hinderliter 2013	Choi 2015	Juraschek 2018	Kucharska 2018	Soric 2019	Said 2020	Hinderliter 2021	Studies	
USA	USA	Brazil	USA	South Korea	USA	Poland	Croatia	Egypt	USA	Country	
RCT	RCT/SB	RCT	RCT/DB	RCT	RCT/Cross over	RCT	RCT	Prospective interventional nonrandomized controlled study	RCT/DB	Study Design	
High Blood Pressure & overweight	Stage 1 hypertensive patient	Hypertensive patient	Hypertensive patient	Hypertensive patients	-	Primary Hypertension	Schizophrenia With Metabolic Syndrome	Obese individuals with hypertension	Hypertensive patients	Health Status	
Both	Both	Both	Both	Female	Female	Both	Both	Both	Both	Sample size and sex	
51	10	105	49	21	70	64	33	46	49	**IG**	Sample Size
24	10	101	49	18	75	62	34	46	49	**CG**	
16	2	24	48	8	4	12	12	12	48	Trial Duration (Week)	
55.1±10	46.1 ± 9.0	NR	52.3±10	73.0 ± 3.9	43.6 ± 7.1	61.34 ± 7.90	53.2±8.9	48.21±6.19	52.3±10	**IG**	Means Age
52.9±9.6	42.4 ± 6.3	NR	51.8±9	73.8 ± 5.8	45.3 ± 8.7	58.11 ± 8.52	50.7±8.0	46.7±6.01	51.8±9	**CG**	
140.1	142.8	143.8	139	135.5	124.6	130.84	130.38	140.34	138.7	**Baseline SBP**	Blood Pressure
83.7	88.8	84.6	85	79.8	83.5	85.16	85.53	NR	85.5	**Baseline DBP**	
32.1±3.6	31.0 ± 5.9	NR	33.5±4.4	25.6 ± 2.5	28.7 ± 4.1	32.61 ± 4.46	28.95±5.21	35.72±5.37	33.5±4.4	**IG**	Means BMI
33.2±3.8	36.9 ± 6.1	NR	33.0±3.9	25.3 ± 2.2	29.7 ± 4.8	33.08 ± 4.27	27.47±3.90	31.5±3.25	33.0±3.9	**CG**	
DASH diet	DASH diet	Standard care +DASH	Dash Diet and Behavioral Weight Management	Weekly DASH nutritional education + ω-3 fatty acid supplements	DASH diet	DASH diet	Dash Diet	Dash Diet	Dash Diet and Behavioral Weight Management	**IG**	Participants
Usual diet	Typical Anerican control diet	Standard care + regular diet	Usual Care	One educational session regarding the DASH diet + ω-3 fatty acid supplements	Usual diet	Standard Recommendations	Standard Hospital Diet	General oral and written information about healthy food choices	Usual Care	**CG**	
Accutracker II	Automatic sphygmomanometer	Electronic sphygmomanometer	MS	NR	Random-zero sphygmomanometer	MS	MS	MS	MS	-	Measurement Tools

Table 4 (Continued)

Moore 2001	Conlin 2003	Azadbakht 2005	Burke 2005	Elmer 2006	Nowson 2009	Al-Solaiman 2009	Chen 2010	Malloy-mcfall 2010	Blumenthal 2010	Smith 2010
USA	USA	Iran	Australia	USA	Australia	USA	USA	USA	USA	USA
RCT	RCT/DB/Cross -Over	RCT	RCT	RCT/DB	Parallel/RCT	RCT/Cross over	RCT	RCT	RCT	RCT/DB
Stage 1 isolated systolic hypertension (ISH)	Hypertensive patient	Metabolic syndrome	Hypertensive patients	Pre-Hypertension or Hypertension	Postmenopausal women with high/Normal BP	Obese hypertensives	Obese individuals with hypertension	Pre- and stage 1 hypertensive	Healthy but overweight with above-normal BP	Hypertensive patient
Both	Both	Both	Both	Both	Female	Both	Both	Both	Both	Both
23	17	11	106	269	46	15	146	10	46	38
25	18	12	98	268	49	15	144	10	49	38
11	10	24	64	72	14	9	11	4	16	16
54.7±8.1	52±11	41.5±12.5	57.1 ± 7.2	50.2±9.3	60.0±4.74	40.3±1.7	44.7±10.7	38.5 ± 10.8	51.8±10	52.3 ± 9.5
53.6±11.8	52 ±8	41.3± 12.18	55.3 ± 7.5	49.5±8.8	58.4±4.9	40.3±1.7	44.7±10.7	38.1 ± 11.1	51.8±9	51.7 ± 9.0
146	151	145	128	134.9	128.3	136.3	131	141.3	137.6	137.5
NR	95	87	77	84.6	80.7	88.6	85	87.9	86.1	87.2
29.0±3.2	32±18	29.8±10.3	30.4 ± 2.9	33.3±6.3	29.5± 4.74	34.5±1.3	28.6±4.0	34.5 ± 8.2	32.8±3.4	32.8±3.4
28.0±3.5	30±5	29.5±9.9	29.7 ± 2.5	32.9±5.6	29.7±29.4	34.5±1.3	27.9±3.8	26.1 ± 2.9	33.0±3.9	32.7 ± 3.9
DASH Diet	Dash Diet +Losartan	DASH diet (500 Kcal less than their needs + 2,400 Mg Na per day)	DASH Diet and physical activity and interactive group workshops handouts of printed information	Recommendations and Dash Diet	Vitality diet (low-sodium DASH-type diet with a low dietary acid load containing 6 servings of 100 g cooked lean red meat per week)	DASH diet	DASH diet	DASH diet	DASH diet	DASH and Weight Management
Control Diet	Control Diet +Placebo	Not given a diet prescription and was simply instructed to "eat as usual."	Usual care	Advice Only	Reference healthy diet (reduce fat intake and increase intake of breads and cereals)	Usual diet, with an average of one fruit and one vegetable (ULFV)	A diet rich in fruits and vegetables	Normal diet	Maintain their usual dietary and exercise habits	Usual care control
Random-zero Sphygmomanometer	Ambulatory BP Monitors	NR	Bioimpedance (TBF 551 body-weight scale; Tanita)	All available measurements	Automated TM2551	A random-zero sphygmomanometer	Random-zero sphygmomanometer	Random-zero sphygmomanometer and stethoscope	Mercury Sphygmomanometer and Stethoscope and An Accutorr Plus BP monitor	Using standardized procedures

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; MS, Mercury Sphygmomanometer.

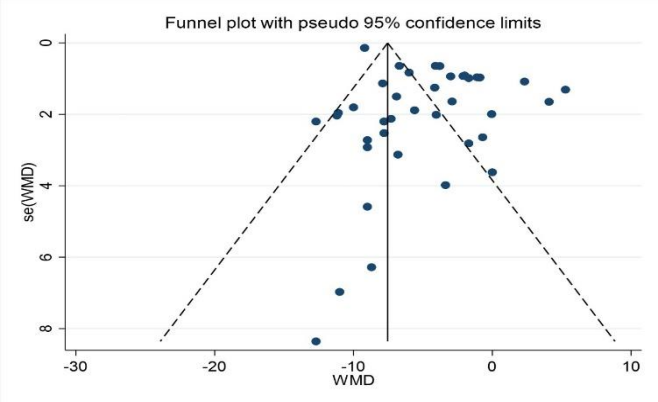

Figure 3A. Publication bias in the studies that evaluated the effect of the DASH diet on SBP

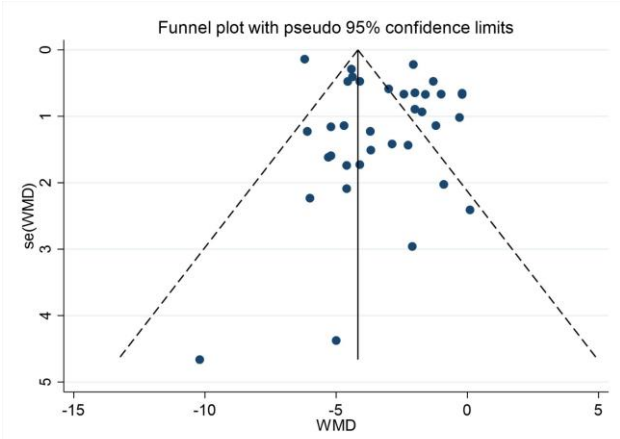

Figure 3B. Publication bias in the studies that evaluated the effect of the DASH diet on DBP

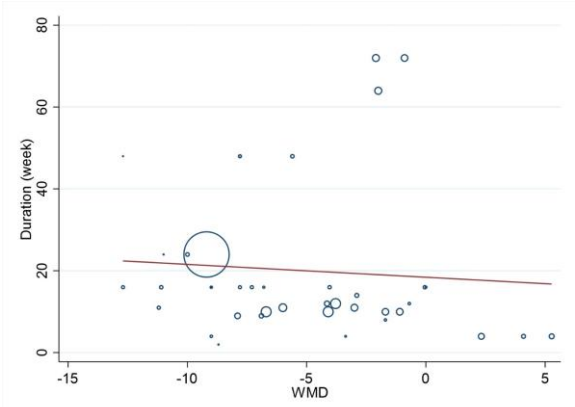

Figure 4A. Correlation between the length of intervention and changes in SBP

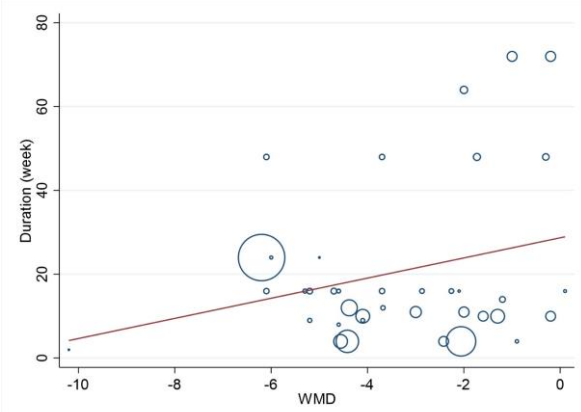

Figure 4B. Correlation between the length of intervention and changes in DBP

Discussion

We conducted a meta-analysis to examine the effect of the DASH diet on reducing both SBP and DBP in individuals with a BMI greater than 25 kg/m². Our results suggest that this dietary approach is an effective non-pharmacological strategy for the management and reduction of blood pressure. Notably, this study represents the first research effort to investigate the effects of the DASH diet specifically in individuals who are both hypertensive and overweight or obese. The results of our study are consistent with previous research indicating that the DASH diet provides significant benefits in reducing blood pressure among overweight or obese adolescents; however, it should be noted that those studies had relatively small sample sizes (55). In addition, another study evaluating the effect of adherence to the DASH diet on the risk of hypertension reported that strong adherence to the diet was associated with a lower risk of hypertension compared with weak adherence (56).

In the subgroup analyses, we observed a statistically significant reduction in SBP among individuals with baseline SBP levels greater than 140 mmHg. Similarly, participants with baseline DBP levels below 85 mmHg showed a significant reduction in DBP following the intervention. Furthermore, interventions lasting longer than 12 weeks were associated with greater and more pronounced reductions in both SBP and DBP, based on the findings of the studies included in our analysis.

Our study specifically focused on individuals who were overweight or obese and had elevated blood pressure, in order to evaluate the effectiveness of the DASH diet on blood pressure control in this population. The observed reductions in SBP and DBP can be attributed to the DASH diet's emphasis on nutrient-dense foods rich in potassium, calcium, magnesium, and fiber, which collectively modulate vascular tone, renal function, and sodium balance.

Although there have been notable advances in pharmacological therapies, such as thiazide diuretics, calcium channel blockers, angiotensin-converting enzyme inhibitors (ACEIs), and angiotensin receptor blockers (ARBs), lifestyle strategies such as adherence to the DASH diet can also have a substantial impact on blood pressure (57-60). This dietary pattern promotes a balanced and heart-healthy eating style by encouraging the consumption of nutrient-rich foods while reducing the intake of high-fat and high-sugar items (61,62). It is characterized by adequate intakes of dietary fiber, potassium (K), calcium (Ca), and magnesium (Mg), along with limited consumption of total fat, saturated fat, cholesterol, and sodium (Na) (61).

Potassium helps relax the walls of blood vessels, thereby contributing to further reductions in blood pressure. In addition, it mitigates the effects of salt by increasing urinary sodium excretion. Increased consumption of potassium-rich foods has been associated with a reduced risk of hypertension and a lower risk of hypertension-related mortality (63-66). Calcium plays a role in maintaining the tone of smooth muscles lining blood vessels, and some studies suggest that adequate calcium intake may be associated with lower rates of high blood pressure (63,67). Magnesium may influence blood pressure by altering extracellular magnesium concentrations, which can affect the production and release of nitric oxide (NO) and modulate arterial smooth muscle tone through its effects on calcium concentrations (68,69). In addition, magnesium may help regulate blood pressure by reducing inflammation and oxidative stress and by binding phosphate in the digestive tract (70-77).

Sodium can influence blood pressure through several mechanisms, including alterations in renal function sensitivity, fluid-regulating hormones, and central sympathetic outflow (78,79). A systematic review concluded that high sodium intake is associated with adverse outcomes, whereas the association with very low sodium intake remains uncertain. Excessive sodium intake can impair the kidneys' ability to excrete fluid effectively, leading to fluid retention and increased blood pressure (80-86).

The body regulates sodium balance through hormones such as aldosterone and glucocorticoids, which control salt and water homeostasis. Increased salt consumption leads to greater sodium excretion while simultaneously promoting water retention by the kidneys. Excessive sodium intake can therefore result in elevated blood pressure, whereas reducing salt intake lowers both systolic and diastolic blood pressure (86-88).

Furthermore, research suggests that high salt intake reduces the sensitivity of central presynaptic sympathoinhibitory α2-adrenergic receptors (α2-AR) to endogenous agonists. This reduction decreases the inhibition of the sympathetic nervous system and increases sympathetic outflow, contributing to elevated blood pressure (90,91).

Conclusion

Recent evidence consistently demonstrates the beneficial effects of the DASH diet in managing blood pressure among overweight and obese individuals. Given the increasing prevalence of hypertension in this population, greater attention has been directed toward effective dietary interventions. This meta-analysis confirms that the DASH diet is an effective non-pharmacological strategy, resulting in significant reductions in both SBP and DBP.

Strengths and limitations

This study has several notable strengths. It represents one of the most comprehensive searches and analyses of available evidence regarding the effect of the DASH diet on blood pressure control in overweight or obese individuals. The search strategy was highly inclusive and covered multiple databases, thereby minimizing the likelihood of missing relevant studies. In addition, the analysis specifically focused on individuals with both elevated blood pressure and overweight or obesity, enhancing the relevance of the findings to this high-risk population.

Nevertheless, several limitations should be acknowledged. The randomized controlled trials included in this meta-analysis varied in sample size and intervention duration. Moreover, participants across the included studies had diverse lifestyles, which may have influenced the outcomes and contributed to heterogeneity.

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Ethical statement

Not applicable.

Conflicts of interest

The authors declare no conflict of interest.

Author contributions

Conceptualization: A. H., V. M., and M. H.; Methodology: M. V.; Data extraction: J. R., K. F., N. M., and G. Y.; Risk of bias assessment: M. V. and H. M.; Validation: V. M. and M. V.; Investigation and data curation: V. M., M. H., and R. J.; Writing-original draft preparation: L. Sh., V. M., and M. H.; Writing-review and editing: M. H. and M. V.; Visualization: V. M. and M. H.; Supervision: M. H.; Project administration: M. H. All authors have read and agreed to the published version of the manuscript.

Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Use of Artificial Intelligence

The authors state that they did not use artificial intelligence or AI-assisted technologies during the writing or literature search for this study.

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