Efficacy of different dietary patterns on lowering of blood pressure level: an umbrella review

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ABSTRACT

Background: Many systematic reviews and meta-analyses have assessed the efficacy of dietary patterns on blood pressure (BP) lowering but their findings are largely conflicting.

Objective: This umbrella review aims to provide an update on the available evidence for the efficacy of different dietary patterns on BP lowering.

Methods: PubMed and Scopus databases were searched to identify relevant studies through to June 2020. Systematic reviews with meta-analyses of randomized controlled trials (RCTs) were eligible if they measured the effect of dietary patterns on systolic (SBP) and/or diastolic blood pressure (DBP) levels. The methodological quality of included systematic reviews was assessed by A Measurement Tool to Assess Systematic Review version 2. The efficacy of each dietary pattern was summarized qualitatively. The confidence of the effect estimates for each dietary pattern was graded using the NutriGrade scoring system.

Results: Fifty systematic reviews and meta-analyses of RCTs were eligible for review. Twelve dietary patterns namely the Dietary Approaches to Stop Hypertension (DASH), Mediterranean, Nordic, vegetarian, low-salt, low-carbohydrate, low-fat, high-protein, low glycemic index, portfolio, pulse, and Paleolithic diets were included in this umbrella review. Among these dietary patterns, the DASH diet was associated with the greatest overall reduction in BP with unstandardized mean differences ranging from −3.20 to −7.62 mmHg for SBP and from −2.50 to −4.22 mmHg for DBP. Adherence to Nordic, portfolio, and low-salt diets also significantly decreased SBP and DBP levels. In contrast, evidence for the efficacy of BP lowering using the Mediterranean, vegetarian, Paleolithic, low-carbohydrate, low glycemic index, high-protein, and low-fat diets was inconsistent.

Conclusion: Adherence to the DASH, Nordic, and portfolio diets effectively reduced BP. Low-salt diets significantly decreased BP levels in normotensive Afro-Caribbean people and in hypertensive patients of all ethnic origins. This review was registered at PROSPERO as CRD42018104733. *Am J Clin Nutr* 2020;112:1584–1598.

Keywords: dietary patterns, systolic blood pressure, diastolic blood pressure, efficacy, umbrella review

Introduction

Hypertension is a major risk factor for cardiovascular disease, the leading cause of death worldwide. It affects ∼1.4 billion people and is likely to exceed 1.6 billion by 2025 (1). Adoption of a healthy diet is one of many approaches widely endorsed for preventing hypertension in the general population.

Research in nutrition has advanced remarkably in recent decades and has established an understanding of the association between dietary habits, foods, and cardiometabolic risk factors, including blood pressure (BP). The concept of an overall "dietary

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Data described in the manuscript, code book, and analytic code will not be made available because our study is an umbrella review using data from previous systematic reviews and meta-analyses. The results were analyzed qualitatively without performing additional statistical analysis.

Supplemental Methods, Supplemental Figure 1, and Supplemental Table 1 are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/ajcn/.

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Abbreviations used: AMSTAR-2, A Measurement Tool to Assess Systematic Review version 2; BP, blood pressure; DASH, Dietary Approaches to Stop Hypertension; DBP, diastolic blood pressure; RCT, randomized controlled trial; SBP, systolic blood pressure; USMD, unstandardized mean difference.

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pattern" has also been developed to counter the limitations of a single nutrient focus leading to paradoxical dietary choices and industry formulations. Dietary patterns represent the overall combination of foods habitually consumed, which together produce synergistic health effects. This approach facilitates dietary recommendations at both individual and population levels (2) with most guidelines now suggesting that dietary patterns play an important role in the primary and secondary prevention of hypertension (3, 4).

Recently, several systematic reviews and meta-analyses of randomized controlled trials (RCTs) have investigated the efficacy of different dietary patterns in lowering BP. Most of these focus on Dietary Approaches to Stop Hypertension (DASH) (5–7), the Mediterranean diet (7–9), and low-salt diet (10–12) but other dietary patterns have also been examined, including vegetarian (13, 14) and Nordic diets (15). Evidence for the efficacy of each of these is often conflicting. For instance, when assessing the possible benefits of a vegetarian diet, 1 study demonstrated significant BP reduction (13) whereas 2 others showed nonsignificant effects (14, 16). The plethora of diets recommended for lowering BP in hypertensive and normotensive people makes it difficult for healthcare providers to offer consistent advice and many dietary approaches lack sufficient evidence to allow their inclusion in guidelines. There is an urgent need for a comprehensive review of the quality of available evidence together with clear recommendations. The term "umbrella review" refers to tertiary research that comprehensively examines evidence from systematic reviews and meta-analyses. An umbrella review can assess the strength and precision of effect estimates and evaluate possible bias in previous systematic reviews. We therefore performed an umbrella review to summarize the available evidence from existing systematic reviews and meta-analyses of RCTs on different dietary patterns and BP lowering effect together with an overview of the methodological quality and credibility of included meta-analyses. The results from this review should assist healthcare providers to offer informed advice as well as identify areas where further research is necessary.

Methods

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline. The protocol of this umbrella review is registered at the PROSPERO website (CRD42018104733).

Study selection

Medline and Scopus databases were searched to identify relevant studies from January 1960 for Scopus and January 1946 for Medline through to 17 June, 2020. Search terms and strategies for each database are presented in the **Supplementary Methods**. Studies identified from both databases were independently selected by 2 reviewers (KS and KA). Disagreement between 2 reviewers was resolved by consensus with a third party (TA). Only systematic reviews with meta-analyses of RCTs were eligible for review if: *1*) study participants were nonhypertensive, *2*) interventions of interest were prescribing dietary patterns, *3*) outcomes of interest were systolic blood pressure (SBP) and/or diastolic blood pressure (DBP), and *4*) pooled effect sizes of interventions were reported, such as unstandardized mean difference (USMD) of SBP and/or DBP between intervention and control groups.

Data extraction.

Data was extracted independently by 2 reviewers (KS and KA). Characteristics of eligible studies, including author's name, year of publication, number of included studies, funding source, conflict of interest (COI), characteristics of study participants including mean age and sex, and characteristics of interventions, including types of dietary pattern, duration of intervention, mode of delivery, and types of comparator were extracted. Primary outcomes of interest were SBP and DBP. The efficacies of each dietary pattern in terms of decreasing SBP and DBP were extracted, including USMD of SBP and DBP and their 95% CIs, as well as the results of heterogeneity between studies (i.e., I^2 statistic or *P* value from the heterogeneity test) and publication bias (i.e., *P* value from Egger's test and Funnel plot).

Risk of bias assessment.

The quality of included systematic reviews was assessed using A Measurement Tool to Assess Systematic Review version 2 (AMSTAR-2) that comprises 16 domains (7 critical domains and 9 noncritical domains). Overall confidence in the results of included systematic reviews was rated as: *1*) high, if the systematic review had no or 1 noncritical weakness, *2*) moderate, if the systematic review had >1 noncritical weakness, *3*) low, if the systematic review had 1 critical flaw with or without noncritical weakness, and *4*) critically low, if the systematic review had >1 critical flaw with or without noncritical weakness. Two reviewers independently performed the risk of bias assessment.

Data analysis.

Results of included studies were qualitatively summarized. Characteristics of included studies were presented as frequency and percentage. USMDs of SBP and DBP for each dietary pattern from the meta-analyses that had the highest quality as assessed by AMSTAR-2 were selected for presentation in the forest plot. In addition, the confidence of the effect estimates for each dietary pattern were graded using NutriGrade, a scoring system used to assess and judge the meta-evidence of RCT and cohort studies in nutrition research (17). The NutriGrade scoring system comprises 7 items with a total score of 10 for systematic reviews and meta-analyses of RCTs. The 7 items include: *1*) risk of bias, study quality, and study limitations (3 points), *2*) precision (1 point), *3*) heterogeneity (1 point), *4*) directness of evidence (1 point), *5*) publication bias (1 point), *6*) funding bias (1 point), and *7*) study design (2 points). Studies with total scores of ≥8, 6–7.99, 4–5.99, and 0–3.99 points were graded as having high, moderate, low, and very low confidence in the effect estimate, respectively.

Results

Our literature search identified 3347 articles for review, of which 50 systematic reviews and meta-analyses of RCTs were included in our umbrella review (see **Figure 1**). Interventions of included systematic reviews and meta-analyses were classified into 12 dietary patterns as follows: DASH diet (*N* = 5) (5–7, 15, 18), Mediterranean diet (*N* = 6) (7–9, 15, 19, 20), vegetarian diet (*N* = 5) (13, 14, 16, 21, 22), low-salt diet (*N* = 11) (7, 10–12, 23–29), low glycemic index diet (*N* = 3) (30–32), low-carbohydrate diet (*N* = 9) (33–41), low-fat diet (*N* = 3) (42–44), high-protein diet (*N* = 7) (45–51), Nordic diet (*N* = 2) (15, 52), Paleolithic diet (*N* = 2) (53, 54), portfolio diet (*N* = 1) (55), and pulse diet (*N* = 1) (56).

Characteristics of included systematic reviews and meta-analyses

Characteristics of included systematic reviews and meta-analyses are presented in **Table 1**. The included systematic reviews and meta-analyses were published between 2010 and 2020. The number of databases applied for searching ranged from 1 to 8, with a median of 4 databases. Most corresponding authors were from the UK (11/50), the USA and Canada (11/50), and Asia (11/50), followed by Europe (10/50), Australia and New Zealand (5/50), South America (1/50), and South Africa (1/50). All included systematic reviews and meta-analyses included primary studies from Europe, North America, South America, Asia, or Australia and New Zealand. Five of the 50 systematic reviews and meta-analyses did not report risk of bias or quality assessments. Governments were the main funding source (23/50) with 2 systematic reviews and meta-analyses funded by the food industry. Twelve systematic reviews and meta-analyses did not report their funding source. The number of primary studies pooled in each meta-analysis ranged from 3 to 89 studies, with the number of enrolled participants ranging from 7 to 5050. The total number of participants was >1000 in 22 of the meta-analyses. The percentage of male participants varied from 0% to 100% and the mean age ranged from 18 to 77 y.

Methodological quality

Overall scores of AMSTAR-2 for each meta-analysis are shown in Table 1, and the scores for single items are summarized in **Supplementary Figure 1**. One (2.0%), 7 (14.0%), 21 (42%), and 21 (42%) of the systematic reviews and meta-analyses were rated as high, moderate, low, and critically low, respectively. The most common critical domain flaws in included studies were failure to mention established review methods prior to conducting the review (64%) and not accounting for risk of bias in individual studies when interpreting the results (36%).

Efficacy of dietary patterns in SBP and DBP reductions

DASH diet.

Five meta-analyses assessed the efficacy of the DASH diet in reducing BP in general populations. Different comparators were applied among these studies [e.g., usual diet, healthy diet, weight-reducing diet (6, 7, 15, 18), and isocaloric diet (5)]. Results from each meta-analysis are presented in **Table 2** and **Figure 2**. There was consistent evidence from 5 meta-analyses of RCTs (5–7, 15, 18) reporting statistically significant reductions for SBP and DBP compared with any control group. The USMDs of SBP and DBP ranged from −3.20 mmHg (95% CI: −4.20, −2.30) to −7.62 mmHg (95% CI: −9.95, −5.29) and from −2.50 mmHg (95% CI: −3.50, −1.50) to −4.22 mmHg (95% CI: −5.87, −2.57), respectively. Three of the 5 included studies reported high heterogeneity between studies (I^2 >50%) (5, 7, 15). One study (5) conducted subgroup analyses of energy intake and types of participants (normotensive and hypertensive). The results of this study found that the DASH diet, with or without energy restriction, significantly decreased SBP and DBP and suggested that the effect was independent of weight reduction. The same study also indicated that DASH significantly reduced SBP and DBP in both normotensive and hypertensive patients.

Results of the NutriGrade assessment are presented in **Supplementary Table 1**. Evidence for the efficacy of the DASH diet was mostly rated as having moderate strength of confidence (3 out of 5 studies) with 2 studies rated as having high confidence.

Mediterranean diet.

There were 6 meta-analyses of RCTs (7–9, 15, 19, 20) assessing the effect of a Mediterranean diet on BP reduction. The included primary studies of these meta-analyses were conducted only in the USA, Italy, France, Poland, Spain, and Israel.

Four out of 6 meta-analyses included participants from the general population and patients with metabolic syndrome (7, 15, 19, 20), whereas 2 meta-analyses included only patients who were obese or overweight and had cardiovascular risk factors (8, 9). In 2 meta-analyses, the comparator was a low-fat diet (8, 9), whereas in 4 meta-analyses comparators differed among the included primary studies (i.e., low-fat diet, usual diet, and high-carbohydrate diet) (7, 15, 19). All meta-analyses reported that a Mediterranean diet significantly decreased DBP compared with control groups, with USMDs ranging from −0.70 mmHg (95% CI: −1.34, −0.07) to −1.99 mmHg (95% CI: −2.28, −1.71) (Table 2 and Figure 2). However, the effects of a Mediterranean diet on SBP were inconsistent in 5 studies. Three meta-analyses (8, 15, 19) found significant benefit from a Mediterranean diet for SBP reduction, with USMDs ranging from −1.45 mmHg (95% CI: −1.97, −0.94) to −3.02 mmHg (95% CI: −3.47, −2.58), whereas 2 meta-analyses reported nonsignificant benefit (7, 9) (Table 2 and Figure 2). One meta-analysis performed stratified analysis according to the types of control diet. This study found that a Mediterranean diet significantly reduced SBP (USMD = −2.99; 95% CI: −3.45, −2.53) and DBP (USMD = −2.0; 95% CI: −2.29, −1.71) when compared with the usual diet. However, the efficacy of a Mediterranean diet was not significant, when compared with other dietary interventions.

The NutriGrade assessment suggests that evidence for the efficacy of a Mediterranean diet on BP reduction had moderate strength of confidence for all included studies (Supplementary Table 1).

Vegetarian diet.

Five meta-analyses of RCTs (13, 14, 16, 21, 22) examined the effect of a vegetarian diet on BP reduction. Four studies involved the general population (13, 14, 21, 22) with 1 including only diabetic patients (16). Evidence was inconsistent across the 5 meta-analyses. Compared with an omnivorous diet, 3 meta-analyses revealed nonsignificant decreases in SBP/DBP

TABLE 1 Characteristics of included systematic reviews and meta-analyses

Author (year)	Dietary intervention	Comparison	No. of studies	Type of included studies	Population	Age	%Male	Total N	Setting	Funding	Country of author	COI	AMSTAR-2
Saneei, 2014 (5)	DASH diet	Isocaloric diet	17	Parallel: 14; crossover: 3	General population	35–60	NR	12–542	NR	Government	Iran	No	Critically low
Siervo, 2015 (6)	DASH diet	Healthy diet/usual care	18	Parallel: 13; crossover: 4	General population	31–60	0 –100	19–537	USA: 9, Australia, New Zealand: 4, Iran: 3	Government	UK	No	Critically low
Gay, 2016 (7)	DASH diet	Weight-reducing diet/healthy diet	24	Parallel/crossover	General population & HT participants	34–67	NR	11–2570	USA: 1, Norway: 1, Iran: 1, Mexico: 1	NR	USA	NR	Low
Ndanuko, 2016 (15)	DASH diet	Healthy diet/usual diet	10	NR	General population	NR	NR	37–810	USA: 5, Brazil: 1, Australia: 3, Iran: 1	No	Australia	No	Low
Filippou, 2020 (18)	DASH diet	Healthy diet/usual diet	30	Parallel: 24; crossover: 6	General population & HT participants	51	45	20–1492	NR	No	Greece	No	Low
Nordmann, 2011 (8)	Mediterranean diet	Low-fat diet	7	Parallel: 7	Overweight/obesity with ≥1 CVD risk factors	34–68	0–86	101–1821	USA: 1, European countries: 4, Israel: 1	Foundation	Israel	No	Low
Huo, 2015 (19)	Mediterranean diet	Low-fat diet/usual diet/high-CBH diet	3	Parallel: 3	General population & T2DM patients	26–77	NR	22–280	USA: 2, Italy: 1	Foundation	China	No	Low
Gay, 2015 (7)	Mediterranean diet	Low-fat diet/usual diet	4	NR	General population & HT patients	34–67	NR	11–2570	USA: 1, Italy: 2, Spain: 1	NR	USA	NR	Low
Nissensohn, 2016 (9)	Mediterranean diet	Low-fat diet	6	Parallel: 6	Overweight/obesity with CVD risk factors	NR	NR	50–2441	USA: 1, European countries: 4, Israel: 1	NR	Spain	No	Critically low
Ndanuko, 2016 (15)	Mediterranean diet	Dietary advice/low-fat diet	3	NR	General population & metabolic syndrome & DM patients	NR	NR	37–810	Italy: 2, Spain: 1	No	Australia	No	Low
Ree, 2020 (20)	Mediterranean diet	Usual diet/other dietary interventions	6	Parallel: 6	General population	NR	NR	NR	NR	Government	UK	No	Low
Yokoyama, 2014 (13)	Vegetarian diet	Omnivore diet	7	Parallel: 4; crossover: 3	General population	38–54.3	17.7–100	11–113	USA: 2, European countries: 1, Australia, New Zealand: 4	Government	Japan	No	Critically low
Viguiliouk, 2017 (16)	Vegetarian diet	Nonvegetarian diet	7	NR	DM patients	32–61 (mean)	47	9–291	NR	Foundation	Canada	Food companies	Low
Picasso, 2017 (14)	Vegetarian diet	Omnivore diet	4	Parallel: 4	General population	NR	NR	20–291	USA: 3, Korea: 1	No	USA	No	Low
Lee, 2020 (21)	Vegetarian diet	Omnivore diet	15	Parallel: 15	General population	33–64	0–50	NR	USA: 10, Australia: 2, New Zealand: 1, South Korea: 1	No	Malaysia	No	Low
Lopez, 2019 (22)	Vegan diet	Omnivore diet, semivegetarian, lacto-ovo-vegetarian	11	Parallel: 11	General population	32–61	17–55	11–345	NR	No	USA	No	Moderate
Suckling, 2010 (11)	Low-salt diet	High-salt diet	13	Parallel: 12; crossover: 1	DM patients	18–NR	NR	7–34	USA: 1, UK: 2, European countries: 4, Australia: 1, Japan: 2, Canada: 1	No	UK	No	Critically low
He, 2013 (26)	Low-salt diet	Usual diet	34	Parallel: 13; crossover: 21	General population & HT participants	18–75	0–100	12–169	NR	No	UK	No	Critically low
Aburto, 2013 (23)	Low-salt diet	Usual diet	36	Parallel/crossover	General population & HT participants	NR	NR	1—2382	Australia, New Zealand, European countries, UK, USA	WHO	USA	No	Moderate
Adler, 2017 (12)	Low-salt diet	Usual diet	6	Parallel: 6	General population & HT participants	38–83	0–100	67–2382	USA: 4, Asia: 1, Australia, New Zealand: 1	Government	UK	No	Low
Gay, 2015 (7)	Low-salt diet	Healthy diet/usual diet	24	Parallel/crossover	General population & HT participants	34–67	NR	11–2570	NR	NR	USA	NR	Low

(*Continued*)

TABLE 1 (*Continued*)

Author (year)	Dietary intervention	Comparison	No. of studies	Type of included studies	Population	Age	%Male	Total N	Setting	Funding	Country of author	COI	AMSTAR-2
Wang, 2015 (27)	Low-salt diet	Usual diet	6	NR	General population & HT participants	38 –66 (mean)	NR	9–5050	China: 6	Government	China	No	Critically low
Kelly, 2016 (10)	Low-salt diet	Healthy diet/usual diet	5	Parallel: 1; crossover: 4	Normotensive people	18–NR	NR	25–1029	USA: 2, Australia: 1, Germany: 1, New Zealand: 1	NR	Australia	No	Critically low
Graudal, 2017 (25)	Low-salt diet	Usual diet	89	Parallel/crossover	General population & HT participants	18–73	0–100	NR	NR	NR	UK	NR	Moderate
Garofalo, 2018 (24)	Low-salt diet	High-salt diet	9	Parallel: 3; crossover: 6	CKD stage1-4	NR	NR	14–302	European countries, Japan, UK, Australia, South Korea, USA	No	Italy	No	Low
Jin, 2020 (29)	Low-salt diet	Usual diet	24	Parallel: 18; crossover: 6	General population	10–69	39–76	50–2052	China: 24	Government	China	Yes	Low
Huang, 2020 (28)	Low-salt diet	High-salt/usual diet	133	NR	General population & HT participants	18–79	0–100	6–1510	USA, UK, European countries, China, Bosnia, Australia, Ghana, Pakistan, Japan	No	Australia	Yes, Government	Moderate
Rebholz, 2012 (48)	High-protein diet	High-CBH diet	40	Parallel: 20; crossover: 15; factorial: 5	General population & HT participants	NR	NR	7–352	USA, European countries, Australia, UAE, Canada, Chile, China, New Zealand	NR	USA	No	Low
Santesso, 2012 (45)	High-protein diet	Low-protein diet	15	Parallel: 6; crossover: 9	General population & HT participants	NR	64	10–405	USA: 9, New Zealand: 1, Australia: 2, UK: 2, Spain: 1	Food company	Canada	Yes, food company	Critically low
Dong, 2013 (47)	High-protein diet	Low-protein diet	5	Parallel: 4; crossover: 1	General population & HT participants	46–63.3	21–48	12–102	USA: 2, UK: 1, European countries: 1, Australia, New Zealand: 1	Foundation	China	No	Critically low
Schwingshackl, 2013 (49)	High-protein diet	Low-protein diet with low-fat diet	11	Parallel: 11	General population & HT participants	35–65	0–100	25–406	NR	NR	Austria	No	Moderate
Tielemans, 2013 (46)	High-protein diet	Low-CBH/low-fat diets	17	Parallel: 12; crossover: 5	General population & HT participants	31–74	0–100	17–273	Canada: 1, USA: 5, Australia: 6, Netherlands: 1	Institution, industry, government	Netherlands	No	Critically low
Zhao, 2018 (50)	High-protein diet	Low-protein diets	12	Parallel: 9; crossover: 3	General population & HT participants	50–63.4 (mean)	NR	8–226	USA: 4, Australia: 4, New Zealand: 1, European countries: 2, UK: 1	No	China	No	Critically low
Yu (2019) (51)	High-protein diet	Low-protein diets	10	Parallel: 10	DM	54–63 (mean)	NR	10–419	NR	NR	China	No	Low
Clar, 2017 (31)	Diet with low glycemic index	Diet with high glycemic index	9	NR	Overweight/obesity	39.8–60	0–90	26–307	USA, UK, Australia, New Zealand, Israel	NR	UK	NR	Low
Evans, 2017 (30)	Diet with low glycemic index	Diet with high glycemic index	14	Parallel: 11; crossover: 3	General population	30–67	0–100	18–773	USA, UK , European countries, Australia, New Zealand, Mexico, Canada	Government	UK	No	Critically low

(*Continued*)

TABLE 1 (*Continued*)

Author (year)	Dietary intervention	Comparison	No. of studies	Type of included studies	Population	Age	%Male	Total N	Setting	Funding	Country of author	COI	AMSTAR-2
Reynolds, 2019 (32)	Diet with low glycemic index	Diet with high glycemic index	4	Parallel: 4	General population	NR	NR	NR	NR	Government, foundation	New Zealand	No	Critically low
Santos, 2012 (39)	Low-CBH diet	Usual diet/low-fat diet/balanced or weight loss diet	10	Parallel: 10	Obesity	NR	NR	120–811	NR	NR	Portugal	No	Critically low
Hu, 2012 (34)	Low-CBH diet	High-CBH with low-fat diet	18	Parallel: 18	Obesity	27–60	0–95	32–403	USA, UK, European countries, Australia, New Zealand, Israel	Government	USA	No	Critically low
Bueno, 2013 (33)	Low-CBH diet	High-CBH with low-fat diet	11	NR	Overweight/obesity	39.8–60	0–90	26–307	USA, UK, European countries, Australia, New Zealand, Israel	Government	Brazil	No	Low
Naude, 2014 (36)	Low-CBH diet	Balanced or weight loss diet	11	Parallel: 11	Overweight/obesity	2–78	NR	NR	USA, European countries, Australia, New Zealand	Government	South Africa	No	Critically low
Mansoor, 2016 (35)	Low-CBH diet	High-CBH with low-fat diet	8	Parallel: 8	Overweight/obesity	42–52	0–91	42–307	USA: 5, Australia, New Zealand: 2, Israel: 1	Foundation	Norway	No	Moderate
Huntriss, 2017 (37)	Low-CBH diet	Usual diet	7	NR	T2DM patients	NR	NR	13–419	NR	Foundation	UK	No	Low
Korsmo-Haugen, 2018 (38)	Low-CBH diet	High-CBH with low-fat diet	14	Crossover: 6; parallel: 8	T2DM patients	NR	NR	13–419	Israel: 1, Japan: 1, Sweden: 1, New Zealand: 1, Australia: 4, USA: 3, UK: 1, Canada: 2	No	Norway	No	Low
Fechner, 2020 (41)	Low-CBH diet	Moderate CBH diet	37	Parallel: 23; crossover: 14	General population	NR	NR	7–200	NR	No	Netherlands	No	Critically low
Dong, 2020 (40)	Low-CBH diet	Usual diet	12	NR	General population	31–65	0–60	42–403	USA, UK, Israel, Australia, China	Government	China	No	Low
Hooper, 2012 (44)	Low-fat diet	Usual diet	6	Parallel: 6	General population	NR	0–100	NR	USA, European countries, Australia, New Zealand, Middle East countries	NR	USA	NR	Critically low
Schwingshackl, 2014 (43)	Low-fat diet	Low-fat diet (total fat< = 30% of TEC)	8	Parallel: 8	IFG & T2DM patients	52–62	40–50	NR	NR	No	Austria	No	Low
Hooper, 2015 (42)	Low-fat diet	Normal fat intake	5	NR	General population	NR	NR	NR	USA, UK	Government	UK	No	High
Ndanuko, 2016 (15)	Nordic diet	Healthy diet/usual diet	3	NR	General population	NR	NR	37–810	Sweden: 1, Denmark: 1, Iceland: 1	No	Austria	No	Low
Ramezani– Jolfaie, 2018 (52)	Nordic diet	Usual diet	4	Parallel: 3; crossover: 1	General population	39–60	NR	21–189	Finland: 2, Sweden: 1, Denmark: 1	Government	Iran	No	Low
Manheimer, 2015 (53)	Paleolithic nutrition diet	Mediterranean/diabetic/ Nordic/isocaloric diet	4	Parallel: 4	Adult with metabolic syndrome/DM	NR	NR	17–70	Sweden: 3, Netherlands: 1	Government	Netherlands	No	Low
Ghaedi, 2019 (54)	Paleolithic nutrition diet	Usual diet, diabetic/Nordic/isocaloric diet	6	Parallel: 5; crossover: 1	Healthy/adult with metabolic syndrome/DM/IHD	NR	0–60.3	13–61	Austria: 1, USA: 1, Sweden: 3, Netherlands: 1	Government	Iran	No	Critically low
Chiavarol, 2018 (55)	Portfolio dietary pattern	NCEP step II diet	5	Parallel: 3; crossover: 2	Hyperlipidemia patients	55.7–65	44%	13–345	Canada: 5	Foundation	Canada	Drug company	Low
Jayalath, 2014 (56)	Pulse dietary pattern	Isocaloric diet	8	Parallel: 6; crossover: 2	General population	28–60	NR	18–121	NR	Government	Canada	Government, industry	Moderate

AMSTAR-2, A Measurement Tool to Assess Systematic Review version 2; CBH, carbohydrate; CKD, chronic kidney disease; COI, conflict of interest; CVD, cardiovascular disease; DASH, Dietary Approaches to Stop Hypertension; DM, diabetes mellitus; HT, hypertension; IHD, ischemic heart disease; IFG, impaired fasting glucose; NCEP, National Cholesterol Education Program; NR, not reported; T2DM, type 2 diabetes mellitus; TEC, total energy consumption; UAE, United Arab Emirates.

TABLE 2 Efficacy of dietary patterns on lowering systolic and diastolic blood pressure

		Systolic blood pressure					Diastolic blood pressure					
Author (year)	Comparison	No. of studies	Total, N	USMD (95% CI)	I^2	Publication bias	No. of studies	Total, N	USMD (95% CI)	I^2	Publication bias	NutriGrade (score)
Dietary Approaches to Stop Hypertension diet												
Saneei (2014) (5)	Isocaloric diet	17	NR	− 6.74 (–8.26, –5.22)	78.9	Yes	17	NR	− 3.59 (–4.35, –2.82)	58.3	Yes	Moderate (7.1)
		14[a]	NR	− 6.82 (–8.55, –5.09)	70.2	NR	14[a]	NR	− 3.59 (–4.41, –2.76)	46.5	NR	
		3[b]	NR	− 6.74 (–8.26, –5.22)	14.3	NR	3[b]	NR	− 3.59 (–4.33, –2.82)	58.3	NR	
Siervo (2015) (6)	Healthy diet/usual diet	17	NR	− 5.20 (–7.00, –3.40)	NR	No	18	NR	− 2.60 (–3.50, –1.70)	NR	No	Moderate (6.15)
Gay (2016) (7)	Weight-reducing diet/healthy diet	4	408	− 7.62 (–9.95, –5.29)	81	No	4	408	− 4.22 (–5.87, –2.57)	92	No	Moderate (6.75)
Ndanuko (2016) (15)	Healthy diet/usual diet	10	3495	− 4.90 (–6.22, –3.58)	70	NR	10	3495	− 2.63 (–3.34, –1.92)	61	NR	High (8.1)
Filippou (2020) (18)	Healthy diet/usual diet	30	5545	− 3.20 (–4.20, –2.30)	35	No	30	5545	− 2.50 (–3.50, –1.50)	72	No	High (8.8)
Mediterranean diet												
Nordmann (2011) (8)	Low-fat diet	6	2650	− 1.70 (–3.35, –0.05)	89	No	6	2650	− 1.47 (–2.14, –0.81)	60	No	Moderate (7.05)
Huo (2015) (19)	Low-fat diet/usual diet/high-CBH diet	3	618	− 1.45 (–1.97, –0.94)	0	No	3	618	− 1.41 (– 1.84, –0.92)	0	No	Moderate (6.5)
Gay (2015) (7)	Low-fat diet/usual diet	4	5121	− 1.17 (–2.81, 0.46)	93	No	4	5121	− 1.44 (–2.11, –0.76)	82	No	Moderate (6.75)
Nissensohn (2016) (9)	Low-fat diet	6	NR	− 1.44 (–2.88, 0.01)	87	NR	6	NR	− 0.70 (–1.34, –0.07)	63	NR	Moderate (7.15)
Ndanuko (2016) (15)	Low-fat diet/usual diet	3	584	− 3.02 (–3.47, –2.58)	0	NR	3	584	− 1.99 (–2.28, –1.71)	0	NR	Moderate (7.5)
Ree (2019) (20)	Usual diet	2	269	− 2.99 (–3.45, –2.53)	0	NR	2	269	− 2.0 (–2.29, –1.71)	0	NR	Moderate (6.15)
	Other dietary interventions	4	448	− 1.5 (–3.92, 0.92)	16	NR	4	448	− 0.26 (–2.41, 1.90)	37	NR	
Vegetarian diet												
Yokoyama (2014) (13)	Omnivore diet	7	NR	− 4.80 (–6.60, –3.10)	0	Yes	7	NR	− 2.20 (–3.50, –1.00)	0	Yes	Low (4.55)
Viguiliouk (2017) (16)	Omnivore diet	7	606	0.10 (–2.33, 2.52)	35	NR	7	606	0.53 (–0.50, 1.57)	0	NR	Moderate (6.15)
Picasso (2017) (14)	Omnivore diet	4	596	− 0.12 (–1.12, 0.88)	0	NR	4	596	0.09 (–1.12, 1.30)	0	NR	Low (5.8)
Lopez (2019) (22)	Omnivore, semivegetarian, pesco-vegetarian, lacto-ovo-vegetarian	11	NR	− 1.33 (–3.50, 0.84)	30	No	11	NR	− 1.21 (–3.06, 0.65)	54	No	Moderate (7.3)
Lee (2020) (21)	Omnivore diet	15	NR	− 2.51 (–3.63, –1.39)	98.42	NR	15	NR	− 1.65 (–2.96, –0.35)	99.39	NR	Moderate (6.8)
Low-salt diet												
Suckling (2010) (11)	High-salt diet	11	135	− 7.04 (–8.71, –5.38)	NR	NR	11	135	− 3.03 (–3.95, –2.11)	NR	NR	Low (5.8)
He (2013) (26)	Usual diet	34	3230	− 4.18 (–5.18, –3.18)	75	Yes	34	3230	− 2.06 (–2.67, –1.45)	68	No	High (8.8)
		4[c]	NR	− 7.11 (–9.13, –5.10)	NR	NR	NR	NR	− 3.13 (–4.28, –1.98)	NR	NR	
		7[d]	NR	− 6.09 (–9.84, –3.95)	NR	NR	NR	NR	− 2.87 (–4.39, –1.35)	NR	NR	
Aburto (2013) (23)	Usual diet	36	6736	− 3.39 (–4.31, –2.46)	65	No	36	6736	− 1.54 (–2.11, –0.98)	60	No	High (9.55)
Adler (2014) (12)	Usual diet	6	3362	− 1.79 (–3.23, –0.36)	NR	NR	5	2754	− 1.17 (–2.08, –0.26)	NR	NR	Moderate (7.65)
Gay (2016) (7)	Healthy diet/usual diet	6	1857	− 2.06 (–3.50, –0.63)	74	No	6	1857	− 1.30 (–2.37, –0.23)	79	No	Moderate (7.25)
Wang (2015) (27)	Usual diet	6	3153	− 6.30 (–7.17, –5.43)	33.5	No	6	3153	− 3.22 (–3.74, –2.70)	17.4	No	Moderate (6.3)
Kelly (2016) (10)	Healthy diet/usual diet	5	1214	− 0.71 (–2.62, 1.20)	54	NR	5	1214	− 0.57 (–1.26, 0.12)	0	NR	Low (5.9)
Graudal (2017) (25)	Usual diet	89[b]	8569	−1.09 (–1.63, –0.56) (Caucasian)	70	NR	90[b]	8569	0.03 (–0.37, 0.43) (Caucasian)	62	NR	Moderate (6.55)
		7[b]	506	− 4.02 (–7.37, –0.68) (black)	87	NR	7[b]	506	− 2.01 (–4.37, 0.35) (black)	81	NR	
		3[b]	393	− 0.72 (–3.86, 2.41) (Asian)	44	NR	3[b]	393	− 1.63 (–3.35, 0.08) (Asian)	0	NR	
		84[a]	5925	−5.51 (–6.45, –4.57) (Caucasian)	75	NR	84[a]	5925	−2.28 (–3.34, –2.32) (Caucasian)	67	NR	
		8[a]	619	− 6.64 (–9.0, –4.27) (black)	60	NR	8[a]	619	− 2.91 (–4.52, –1.30) (black)	65	NR	
		9[a]	501	− 7.75 (–11.44, –4.07) (Asian)	78	NR	9[a]	501	− 2.68 (–4.21, –1.15) (Asian)	47	NR	
Garofalo (2018) (24)	Usual diet	9	1044	− 4.9 (–6.8, –3.1)	0	No	9	1044	− 2.3 (–3.5, –1.2)	0	No	Moderate (7.4)
Jin (2020) (29)	Usual diet	24	NR	− 7.0 (–8.4, 5.7) (Asian)	NR	No	24	NR	− 3.6 (–4.5, 2.76) (Asian)	NR	No	Low (5.25)
Huang (2020) (28)	Usual diet	133	12197	− 4.26 (–4.89, –3.62)	77.8	Yes	133	12197	− 2.07 (–2.48, –1.67)	76.6	Yes	High (8.00)

(*Continued*)

TABLE 2 (*Continued*)

Author (year)	Comparison	Systolic blood pressure: No. of studies	Systolic: Total, N	Systolic: USMD (95% CI)	Systolic: I^2	Systolic: Publication bias	Diastolic blood pressure: No. of studies	Diastolic: Total, N	Diastolic: USMD (95% CI)	Diastolic: I^2	Diastolic: Publication bias	NutriGrade (score)
Low glycemic index												
Clar (2017) (31)	High glycemic index diets	10	786	0.52 (–1.21, 2.25)	7	NR	10	786	– 0.23 (–1.42, 0.96)	38	NR	Low (4.4)
Evans (2017) (30)	High glycemic index diets	14	1097	– 1.13 (–2.51, 0.25)	9	No	14	1097	– 1.26 (–2.30, –0.22)	20	No	High (8.05)
Reynolds (2019) (32)	High glycemic index diets	4	916	– 0.17 (–1.03, 0.69)	NR	NR	NR	Low (4.00)				
Low-carbohydrate diet												
Santos (2012) (39)	Usual diet/low-fat diet/balanced weight diet	10	2590	– 4.80 (–5.53, –4.29)	77	NR	10	2590	– 3.10 (–3.45, –2.74)	77	NR	Low (4.4)
Hu (2012) (34)	High-CBH with low-fat diet	18	NR	– 1.0 (–3.5, 1.5)	91.7	No	18	NR	– 0.7 (–1.6, 0.2)	40.8	No	Low (5.8)
Bueno (2013) (33)	High-CBH with low-fat diet	11	1298	– 1.47 (–3.44, 0.50)	33	No	11	1298	– 1.43 (–2.49, –0.37)	3	Yes	High (9.05)
Naude (2014) (36)	Balanced weight loss diet	7[e]	1057	– 1.26 (–2.67, 0.15)	0	NR	8[e]	1362	– 0.08 (–1.53, 1.36)	51	NR	Low (5.2)
		4[d]	545	0.61 (–3.14, 4.36)	40	NR	4[d]	545	0.77 (–1.77, 3.30)	39	NR	
Mansoor (2016) (35)	High-CBH with low-fat diet	8	NR	– 1.02 (–2.98, 0.94)	63.1	Yes	8	NR	– 1.01 (–2.75, 0.74)	77.9	Yes	High (8.9)
Huntriss (2017) (37)	Usual diet	7	718	– 2.74 (–5.27, –0.20)	43	NR	7	718	– 0.99 (–2.24, 0.25)	15	NR	Moderate (6.95)
Korsmo-Haugen (2018) (38)	High-CBH with low-fat diet	14	1179	– 0.93 (–2.24, 0.37)	0	No	12	944	– 0.21 (–1.20,0.79)	0	No	High (8.85)
Fechner (2020) (41)	Moderate-CBH diet	24	NR	– 1.10 (–2.53, 0.33)	75.4	NR	24	NR	– 1.07 (–2.10, –0.05)	77	NR	Very low (3.8)
Dong (2020) (40)	Usual diet	12	3270	– 1.41 (–2.26, –0.56)	0	No	10	2826	– 1.71 (–2.36, –1.06)	14	No	High (9.0)
Low-fat diet												
Hooper (2012) (44)	Usual diets	6	3981	– 0.56 (–11.22, 1.06)	0	NR	6	3543	– 0.35 (–0.96, 0.26)	0	NR	Moderate (6.15)
Schwingshackl (2014) (43)	High-fat diets	7	659	– 0.59 (–3.36, 2.18)	47.6	Yes	8	827	1.30 (0.87, 1.73)	0	Yes	Moderate (7.3)
Hooper (2015) (42)	Normal fat intake	5	3812	– 0.19 (–1.36, 0.97)	0	NR	5	3812	– 0.36 (–1.03, 0.32)	0	NR	Moderate (7.4)
High-protein diet												
Rebholz (2012) (48)	Low-CBH diets	29	2594	– 1.76 (–2.33, –1.20)	0	No	29	2594	– 1.15 (–1.59, –0.71)	0	No	Moderate (6.8)
Santesso (2012) (45)	Lower protein diets	15	1186	– 0.21 (–0.32, –0.09)	0	NR	15	1186	– 0.18 (–0.29, –0.06)	2	NR	Moderate (7.3)
Dong (2013) (47)	Low-protein diets	5	298	– 3.13 (–6.58, 0.32)	19.2	Yes	4	196	– 1.86 (–4.26, 0.56)	19.2	NR	Low (5.5)
Schwingshackl (2013) (49)	Low-protein diet with low-fat diets	11	1414	– 1.61 (–3.45, 0.23)	41	Yes	11	1402	– 0.42 (–1.37, 0.54)	0	Yes	Moderate (6.6)
Tielemans (2013) (46)	Low-fat/low-CBH diets	14	1208	– 2.11 (–2.86, –1.37)	0	NR	NR	Low (4.6)				
Zhao (2018) (50)	Low-protein diets	12	455	– 0.08 (–0.21, 0.05)	0	No	11	405	– 0.08 (–0.22, 0.06)	13	No	Moderate (7.55)
Yu (2019) (51)	Low-protein diets	10	1138	– 0.27 (–0.47, –0.06)	46	No	10	1138	– 0.64 (–1.80,0.52)	68	No	Moderate (7.4)
Nordic diet												
Ramezani–Jolfae (2018) (52)	Usual diets	4	492	– 3.97 (–6.40, –1.54)	26.1	No	4	492	– 2.08 (–3.44, –0.73)	0	No	Moderate (6.25)
Ndanuko (2016) (15)	Healthy diet/usual diet	3	306	– 5.20 (–7.30, –3.11)	0	NR	3	306	– 3.85 (–5.50, –2.19)	0	NR	Moderate (7.5)
Paleolithic nutrition diet												
Manheimer (2015) (53)	Other diets, Mediterranean/diabetic/Nordic/isocaloric diets	4	159	– 3.64 (–7.36, 0.08)	0	NR	4	159	– 2.48 (–4.98, 0.02)	0	NR	Moderate (6.75)
Ghaedi (2019) (54)	Usual diet/ diabetic/Nordic/isocaloric diet	6	222	– 4.75 (–7.54, –1.96)	6.4	NR	6	222	– 3.23 (–4.77, –1.69)	0	NR	Low (4.9)
Portfolio dietary pattern												
Chiavaroli (2018) (55)	NCEP step II diet	5	439	– 1.75 (– 3.23, –0.26)	0	NR	5	439	-1.36 (– 2.33, –0.38)	0	NR	Moderate (7.0)
Pulse dietary pattern												
Jayalath (2014) (56)	Isocaloric diet	8	554	– 2.25 (–4.22, –0.28)	73	NR	8	554	– 0.71 (–1.74, 0.31)	58	NR	Moderate (6.15)

[a]Hypertensive patients, [b]Normotensive people, [c]Type 1 diabetes patients, [d]Type 2 diabetes patients, [e]Obese patients.
USMDs were estimated from fixed or random effect model. I^2 refers to the degree of heterogeneity. Publication bias was assessed from Egger's test or Funnel plot.
CBH, carbohydrate; NCEP, National Cholesterol Education Program; NR, not reported; USMD, unstandardized mean difference.

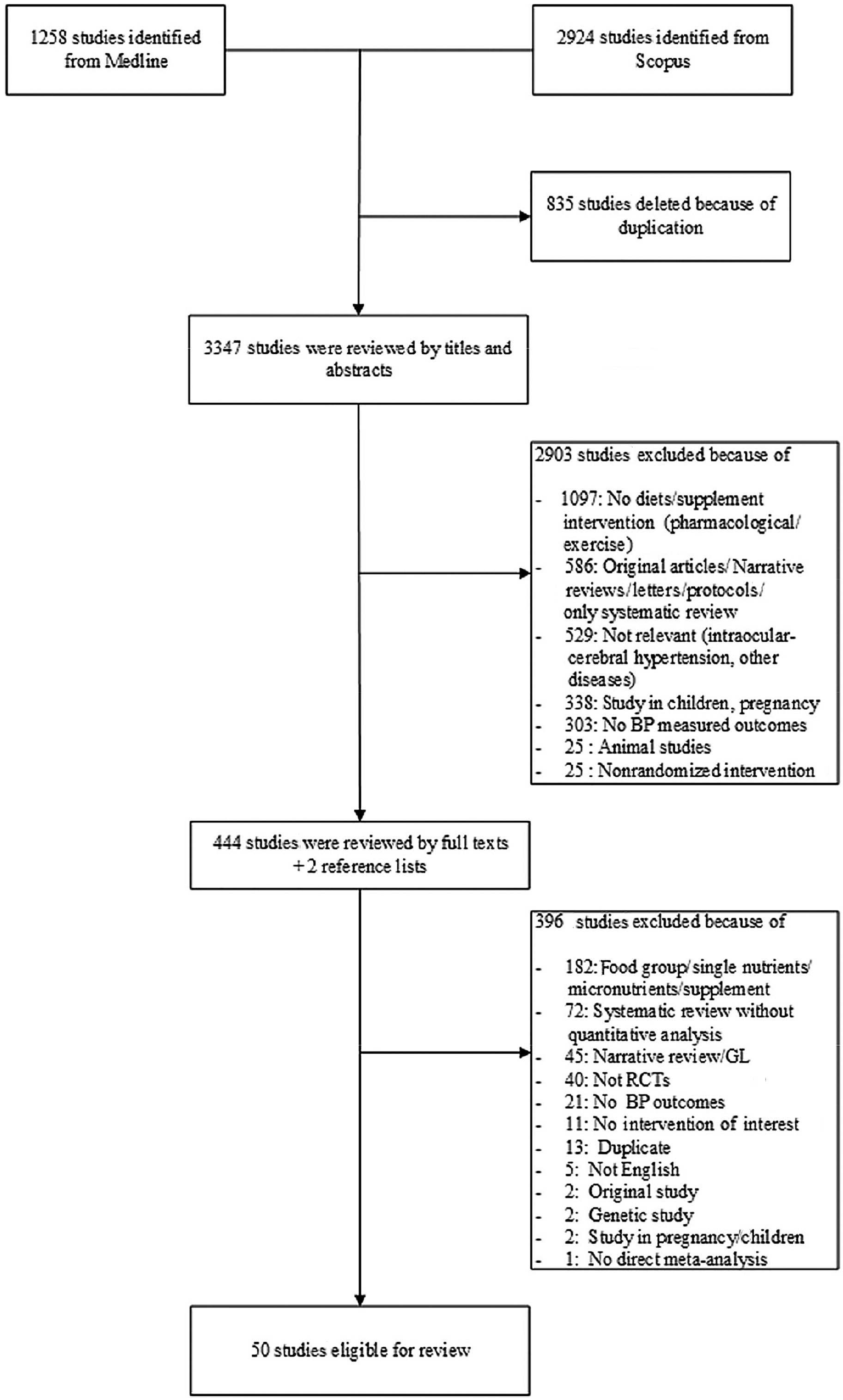

FIGURE 1 Flow chart of study selection. BP, blood pressure; RCT, randomized controlled trial.

(14, 16, 22). The remaining 2 meta-analyses reported significant decreases in SBP/DBP with USMDs ranging from −4.80 mmHg (95% CI: −6.6, −3.1) to −2.51 (95% CI: −3.63, −1.39) for SBP and from −2.20 (95% CI: −3.50, −1.00) to −1.65 (95% CI: −2.96, −0.35) for DBP, see Table 2 and Figure 2. However, these studies were assessed as having low (21) and critically low quality (13) based on the AMSTAR-2 quality assessment. Evidence for the efficacy of a vegetarian diet was rated as having moderate and low confidence in 2 and 3 studies, respectively.

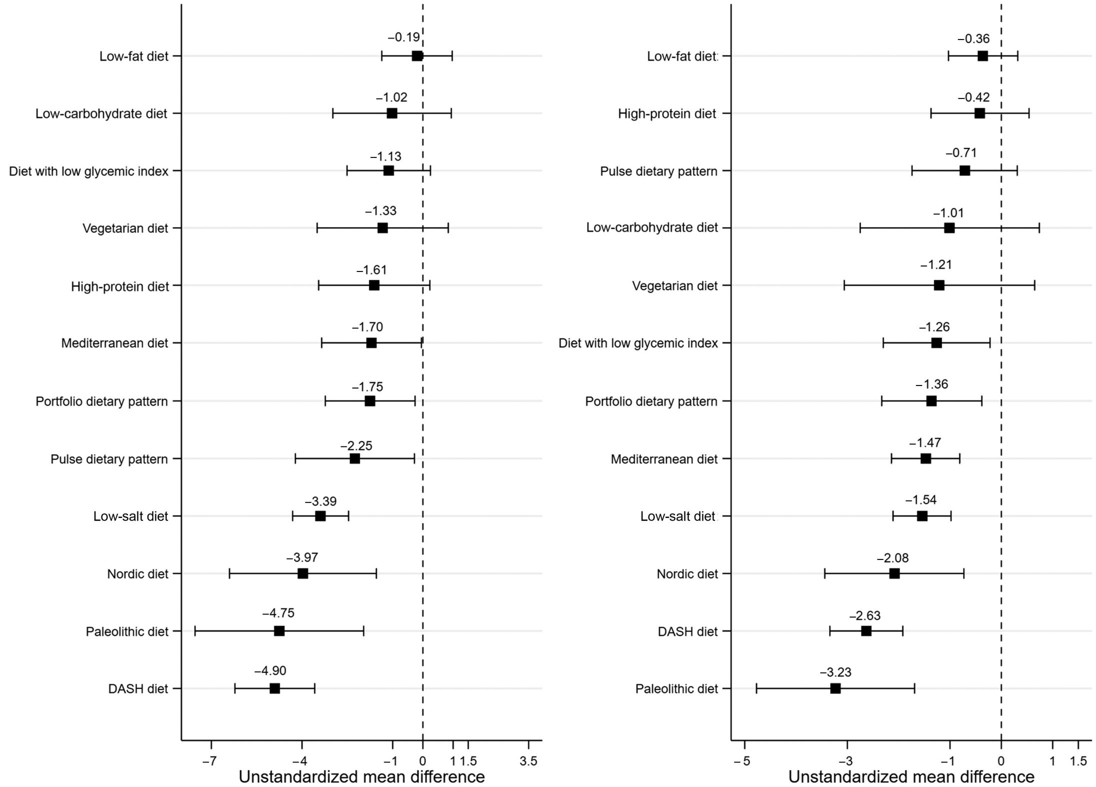

FIGURE 2 Pooled mean differences of systolic and diastolic blood pressures of different dietary patterns. DASH, Dietary Approaches to Stop Hypertension.

Low-sodium diet.

Eleven meta-analyses of RCTs analyzed the efficacy of a low-sodium/salt diet (7, 10–12, 23–29) in BP reduction. The numbers of participants in these interventions were higher than in other interventions. Seven out of 11 studies included 1000–5000 participants (7, 10, 12, 24, 26, 27, 29) and 3 studies included >5000 participants (23, 25, 28). Eight meta-analyses were general population based, including participants with and without a history of hypertension (7, 12, 23, 25–29). One meta-analysis included only normotensive people (10), whereas 2 meta-analyses included high-risk populations, namely chronic kidney disease stage 1–4 (24) and diabetes mellitus (11). The included meta-analyses compared a low-salt diet with usual or other healthy diets. Low-salt/sodium diets significantly reduced SBP and DBP in 8 meta-analyses (7, 11, 12, 23, 24, 26, 27) with USMDs of SBP ranging from −4.14 (95% CI: −5.84, −2.43) to −7.04 (95% CI: −8.71, −5.38) and USMDs of DBP ranging from −1.17 (95% CI: −2.08, −0.26) to −3.22 (95% CI: −3.74, −2.70) (Table 2 and Figure 2). For the remaining 2 nonsignificant studies, results from Kelly et al. (10) and Jin et al. (29) showed that sodium reduction did not significantly decrease SBP and DBP in normotensive participants when compared with usual or healthy diets. A study by Graudal et al. (25) performed subgroup analyses according to ethnicity and BP status. Their results showed that in normotensive Afro-Caribbean and Caucasian populations low-sodium diets significantly reduced SBP but in normotensive Asians no statistically significant reduction was observed. For hypertensive participants, reductions were statistically significant for both SBP and DBP in all 3 ethnic groups, with the greatest reductions in Asian and Afro-Caribbean people.

According to the NutriGrade assessment, 5, 3, and 3 meta-analyses of a low-sodium diet were graded as having moderate, high, and low confidence, respectively.

Low glycemic index diet.

Three meta-analyses investigated the effect of a low glycemic index diet (30–32). Two of these included general population participants (30, 32), whereas the other included obese/overweight populations (31). Findings from the 3 studies suggested that SBP in the low glycemic index group was not significantly different from SBP in a high glycemic index diet group. For reducing DBP, the results of 2 meta-analyses were inconsistent in that 1 study reported a nonsignificant effect (USMD = −0.23; 95% CI: −1.42, 0.96) (31) whereas another found a significant effect for a low glycemic index diet (USMD = −1.26; 95% CI: −2.30, −0.22) (30) (Table 2 and Figure 2). Evidence from the study reporting significant efficacy for a low glycemic index in reducing DBP was rated as having high confidence, and evidence for the 2 meta-analyses suggesting nonsignificant benefit was graded as low.

Low-carbohydrate diet.

Two out of 8 meta-analyses examining low-carbohydrate diets assessed the effect of a very low-carbohydrate/ketogenic diet (<50 g carbohydrate per day) (33) and the Atkins diet (20–40 g carbohydrate per day or <20% of total energy intake) (35) compared with a conventional low-fat diet in overweight/obese patients. Results of each meta-analysis are presented in Table 2 and Figure 2. Consumption of a very low-carbohydrate/ketogenic diet and Atkins diet decreased SBP and DBP but the results failed to reach statistical significance [USMDs of SBP ranging from −1.47 (95% CI: −3.44, 0.50) to −1.02 (95% CI: −2.98, 0.94) and USMDs of DBP ranging from −1.43 (95% CI: −2.49, −0.37) to −1.01 (95% CI: −2.75, 0.74)]. Seven studies examined the effects of all types of low-carbohydrate diets, including low- and very low-carbohydrate, compared with a conventional low-fat diet, usual diet, and other balanced weight-loss diet in a general population, obese subjects, and diabetic patients. The results reveal differences in the direction of treatment effect and statistical significance of the effect (34, 36–39). The mean differences of SBP ranged from −4.80 (95% CI: −5.53, −4.29) to 0.61 (95% CI: −3.14, 4.36) with the mean differences of DBP ranging from −3.10 (95% CI: −3.45, −2.74) to 0.77 (95% CI: −1.77, 3.30). Three meta-analyses of the efficacy of a low-carbohydrate diet had their evidence graded as high confidence and 1 as moderate, whereas 3 were rated as low and 1 as very low.

Low-fat diet.

Three meta-analyses assessed the effects of a low-fat diet. One study compared this with a high-fat diet in patients with impaired fasting glucose or type 2 diabetes mellitus (43) and the other 2 compared this with the usual diet in a general population (42, 44). The results of these meta-analyses showed no significant difference in SBP and DBP between a low-fat diet and high-fat or usual diet. Evidence for efficacy of a low-fat diet was rated as having moderate confidence for all studies (Supplementary Table 1).

High-protein diet.

Six meta-analyses looked at the efficacy of a high-protein diet in reducing BP in a general population with and without a history of hypertension (45–50), with 1 meta-analysis including only patients with diabetes (51). The comparators were low-protein diet (45, 47, 50, 51), low-protein and low-fat diet (49), low-protein and low-carbohydrate diet (46), and low-carbohydrate diet (48). Three meta-analyses showed that a high-protein diet had marginal benefit for SBP/DBP reduction but failed to reach statistical significance (47, 49, 50). However, findings from 4 meta-analyses suggested a small beneficial effect from a high-protein diet on reducing BP in a general population (45, 46, 48) and in diabetic patients (51). SBP in the high-protein diet groups was significantly lower than SBP in the low-protein diet groups (USMD ranging from −0.21; 95% CI: −0.32, −0.09 to −0.27; 95% CI: −0.47, −0.06) (45, 51), low-carbohydrate and low-fat diet groups (USMD = −2.11; 95% CI: −2.86, −1.37) (46), and low carbohydrate diet groups (USMD = −1.76; 95% CI: −2.33, −1.20) (48). The mean differences of DBP ranged from −0.18 (95% CI: −0.29, −0.06) to −1.15 (95% CI: −1.59, −0.71) (45, 48) (Table 2 and Figure 2). Most of the meta-analyses for the efficacy of a high-protein diet were rated as having moderate confidence, whereas 2 meta-analyses were rated as having low confidence.

Nordic diet.

The Nordic diet emphasizes a high consumption of whole grains, root vegetables, legumes, berries, fatty fish, and a low consumption of sweets and red meat. Two meta-analyses examined the effects of a Nordic diet in a general population (15, 52). All primary studies included in these meta-analyses were conducted only in Scandinavian and Nordic regions. The results of both meta-analyses were consistent in showing that a Nordic diet could significantly lower SBP and DBP when compared with usual/other healthy diets. USMDs of SBP ranged from −3.97 (95% CI: −6.40, −1.54) to −5.20 (95% CI: −7.30, −3.11) and USMDs of DBP ranged from −2.08 (95% CI: −3.44, −0.73) to −3.85 (95% CI: −5.50, −2.19) (Table 2 and Figure 2). There was a mild degree of heterogeneity between studies for both meta-analyses. Evidence for the efficacy of a Nordic diet was rated as having moderate confidence.

Paleolithic diet.

A Paleolithic diet is a dietary approach based on foods that might have been eaten during the Paleolithic era (from ∼2.5 million to 10,000 y ago). Typically, this includes lean meat, fish, fruit, vegetables, nuts and seeds, foods that in the past could have been obtained by hunting and gathering. This diet limits foods that became common when farming emerged about 10,000 y ago, including dairy products, legumes, and grains (57). One meta-analysis (53) showed that a Paleolithic diet marginally lowered BP when compared with other healthy diets but failed to reach significance. The USMDs of SBP and DBP were −3.64 (95% CI: −7.36, 0.08) and −2.48 (95% CI: −4.98, 0.02), respectively (Table 2). However, an updated meta-analysis that included 2 additional RCTs found that a Paleolithic diet significantly decreased SBP and DBP, with USMDs of −4.75 (95% CI: −7.54, −1.96) and −3.23 (95% CI: −4.77, −1.69) (54) (Figure 2). Evidence for these studies was graded as having moderate and low confidence.

Portfolio dietary pattern.

The portfolio diet is a plant-based dietary pattern that combines recognized cholesterol-lowering foods (e.g., nuts, plant protein, viscous fiber, and plant sterols) (55). One meta-analysis assessing the effect of a portfolio diet on BP reduction (55) included 5 RCTs conducted in Canada, each published by the same group of researchers. The consumption of a portfolio diet significantly reduced SBP/DBP when compared with the National Cholesterol Education Program (NCEP) II diet. The USMDs of SBP and DBP were −1.75 (95% CI: −3.23, −0.26) and −1.36 (95% CI: −2.33, −0.38), respectively (Table 2 and Figure 2). Evidence for the efficacy of a portfolio dietary pattern was rated as having moderate confidence.

Pulse dietary pattern.

The pulse diet is characterized by a high consumption of dried seeds and legumes high in fiber, plant protein, and various micronutrients, and a low consumption of fat and high glycemic index foods. One meta-analysis, including 8 RCTs, assessed the effect of a pulse dietary pattern on SBP/DBP (56). There was a significant reduction in SBP compared with other isocaloric diets with USMD = −2.25 (95% CI: −4.22, −0.28) but for DBP the results failed to reach statistical significance [USMD = −0.71 (95% CI: −1.74, 0.31)] (Table 2 and Figure 2). Evidence for the pulse dietary pattern was rated as having moderate confidence (Supplementary Table 1).

Discussion

Principal findings

This umbrella review summarizes evidence for the effect of different dietary patterns on BP reduction. Our results found that DASH, Nordic, and portfolio dietary patterns significantly decreased SBP and DBP in the general population. Among these dietary patterns, the DASH diet was associated with the greatest overall reduction in BP with USMDs ranging from −3.20 mmHg (95% CI: −4.20, −2.30) to −7.62 mmHg (95% CI: −9.95, −5.29) for SBP and from −2.50 mmHg (95% CI: −3.50, −1.50) to −4.22 mmHg (95% CI: −5.87, −2.57) for DBP. A low-salt/sodium diet also significantly reduced BP but the benefit of this diet was mainly found in patients diagnosed with hypertension. Evidence was inconsistent for the efficacy of a Mediterranean diet, vegetarian diet, low glycemic index diet, low-carbohydrate diet, high-protein diet, Paleolithic diet, and pulse dietary pattern. A low-fat diet did not have significant effects on BP reduction.

Findings in the context of the literature

The consistency of evidence in our umbrella review supporting significant reductions of both SBP and DBP in DASH, Nordic, and portfolio dietary patterns may be attributable to shared foods encouraged in these dietary patterns. They are rich in fruits, vegetables, whole grains, legumes, seeds, nuts, fish, and dairy products and low in processed meats, saturated fat, and sweets. The antihypertensive effect of these foods is linked to the synergistic effects of important nutrients, such as magnesium, potassium, calcium, phytochemicals, and antioxidants such as polyphenols, vitamins, unsaturated fatty acids, and fiber, each of which has been shown to lower BP (58, 59). The beneficial effect of DASH highlighted in our umbrella review is in agreement with the recently published network meta-analysis by Schwingshackl et al. (58), which found DASH to be the most effective dietary approach for lowering BP in both prehypertensive and hypertensive patients. Observed reductions in DBP and SBP with the DASH dietary pattern are clinically meaningful, based on existing evidence that it can lower SBP by around 5–8 mmHg and DBP by around 3–4 mmHg. Prospective studies show that a 2 mmHg reduction in SBP and DBP is associated with lower mortality from stroke (10%) and coronary artery disease (7%) in middle-aged men and women (60, 61). The DASH diet has several subtypes including DASH with and without energy restriction and DASH higher protein. The efficacy of these subtypes might be dissimilar in terms of lowering SBP and DBP. Our results found that the DASH diet with or without energy restriction could significantly reduce SBP and DBP but the efficacy of DASH higher protein was not significant when compared with a low-fat diet.

The Mediterranean diet is associated with a low concentration of inflammatory biomarkers which may play a protective role in reducing cardiovascular events (62). In our review, we found that adherence to a Mediterranean diet may reduce BP levels. Every meta-analysis reported that a Mediterranean diet significantly decreased DBP compared with control groups. However, evidence for the effect of a Mediterranean diet on SBP reduction is inconsistent in terms of statistical significance. The USMDs of SBP of the significant studies ranged from −1.45 (95% CI: −1.97, −0.94) to −3.02 (95% CI: −3.47, −2.58), which is debatable in terms of clinical significance. These inconsistent findings may result from the different settings and control diets among the primary studies included in the systematic reviews and meta-analyses. These primary studies were usually conducted in Italy, Greece, Spain, and the USA which have different eating patterns. Even though they applied the Mediterranean diet as an intervention of interest, details of individual diets could differ.

The vegetarian, Paleolithic, portfolio, and pulse diets are plant-based dietary patterns that favor foods such as vegetables and fruits. Our umbrella review demonstrated that among 4 different plant-based dietary patterns, only the portfolio diet was associated with significant reductions in SBP and DBP. However, this effect was minimal (USMD = −1.75 mmHg for SBP and −1.36 mmHg for DBP) and might not have clinical significance. The results based on these dietary approaches should be interpreted with caution, since in our review ≤3 meta-analyses were available for each dietary pattern. A recent umbrella review of systematic reviews of meta-analyses of observational and interventional studies showed that vegetarian diets are associated with a reduced risk of ischemic heart disease (63). This suggests that these dietary patterns may provide alternative cardiovascular advantages beyond BP control. Further research is needed to confirm or refute this.

Across all dietary patterns in our review the largest number of meta-analyses ($N = 9$) involved low-sodium/salts diets. Most of these (8/9) were very large trials ($N > 1000$). Our review shows sodium restriction to have a BP-lowering effect in most meta-analyses (7/9). We also found that the effect is more consistent in people with hypertension and is greater in Afro-Caribbean and Asian populations than it is with Caucasians (25). Existing evidence therefore suggests that any low-salt diet may potentially reduce BP, especially in certain racial groups and for hypertensive patients.

More recently, interest has extended into macronutrients, including proteins, fats, and carbohydrates, with many clinical trials investigating the effects of these on BP. Results from the meta-analysis of RCTs included in this umbrella review reflect uncertainty over the effect of these dietary interventions. This accords with existing evidence that the effect on cardiovascular mortality and morbidity of low-fat, low-carbohydrate, high-protein diets remains a debatable issue (64–68).

Strengths and limitations

Our umbrella review has several strengths, including the systematic searching, collecting, and assessment of the strength and credibility of evidence derived from various systematic reviews. We included data only from meta-analysis of RCTs, incorporating new trial data up to 2020 and covering a wide range of dietary approaches, participants, and studies. Our review comprehensively evaluates the methodological quality of meta-analyses and assesses the quality of evidence for outcomes from published meta-analyses of RCTs. Nevertheless, our findings need to be considered in the light of some limitations. Firstly, in terms of methodological quality, most of the included meta-analyses were rated as low or critically low (42% and 42%, respectively). Furthermore, the high level of heterogeneity across existing trials should be noted in terms of baseline characteristics of patients and interventions. Although the dietary patterns identified may have shared some common basic characteristics they were not homogenous, each diet being set in a unique cultural context.

Perspectives/implication

The potential benefits identified in this review suggest that in broad terms the adoption of a DASH diet, as recommended in many clinical practice guidelines, should continue to be promoted as a public health goal. However, it should be noted that the diets under review are largely based on Western eating habits and traditions. Eating patterns are culturally sensitive and vary significantly in different settings. The widespread adoption of any medically beneficial diet requires it to incorporate readily available foodstuffs that are both affordable and gastronomically acceptable across a range of tastes and regions.

Although we have seen that BP can be reduced by modifying diet, studies are needed to assess whether or not these levels of reduction impact on long-term mortality and morbidity. Finally, there is no data relating quality of life to the difficulties of adhering to dietary restrictions. For example, the likely adverse effects and impact on quality of life from restricting dietary protein should be studied before being recommended for widespread use.

Conclusion

Our results found that adherence to the DASH diet effectively reduced BP. Low-salt diets significantly decreased BP levels in normotensive Afro-Caribbean people and in hypertensive patients of all ethnic origins. Other dietary patterns such as the Nordic and portfolio diets also significantly decreased BP levels, but confidence in the evidence for these dietary patterns is moderate due to the low number of primary studies. Large RCTs are needed to confirm the benefits of these approaches.

The authors' contributions were as follows—KS, PV, and TA: designed the research; KS, KA, and TA: conducted the research; KS and TA: analyzed data; KS: wrote the manuscript; AD, PV, and TA: critically revised the manuscript; KS: had primary responsibility for the final content; and all authors: read and approved the final manuscript. The authors report no conflicts of interest.

References

1. Mills KT, Bundy JD, Kelly TN, Reed JE, Kearney PM, Reynolds K, Chen J, He J. Global disparities of hypertension prevalence and control: a systematic analysis of population-based studies from 90 countries. Circulation 2016;134(6):441–50.
2. Mozaffarian D. Dietary and policy priorities for cardiovascular disease, diabetes, and obesity: a comprehensive review. Circulation 2016;133(2):187–225.
3. Williams B, Mancia G, Spiering W, Agabiti Rosei E, Azizi M, Burnier M, Clement DL, Coca A, de Simone G, Dominiczak A, et al. 2018 ESC/ESH guidelines for the management of arterial hypertension. Eur Heart J 2018;39(33):3021–104.
4. Whelton PK, Carey RM, Aronow WS, Casey DE Jr, Collins KJ, Dennison Himmelfarb C, DePalma SM, Gidding S, Jamerson KA, Jones DW, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: executive summary: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. Circulation 2018;138(17):e426–e83.
5. Saneei P, Salehi-Abargouei A, Esmaillzadeh A, Azadbakht L. Influence of Dietary Approaches to Stop Hypertension (DASH) diet on blood pressure: a systematic review and meta-analysis on randomized controlled trials. Nutr Metab Cardiovasc Dis 2014;24(12):1253–61.
6. Siervo M, Lara J, Chowdhury S, Ashor A, Oggioni C, Mathers JC. Effects of the Dietary Approach to Stop Hypertension (DASH) diet on cardiovascular risk factors: a systematic review and meta-analysis. Br J Nutr 2015;113(1):1–15.
7. Gay HC, Rao SG, Vaccarino V, Ali MK. Effects of different dietary interventions on blood pressure: systematic review and meta-analysis of randomized controlled trials. Hypertension 2016;67(4):733–9.
8. Nordmann AJ, Suter-Zimmermann K, Bucher HC, Shai I, Tuttle KR, Estruch R, Briel M. Meta-analysis comparing Mediterranean to low-fat diets for modification of cardiovascular risk factors. Am J Med 2011;124(9):841–51.e2.
9. Nissensohn M, Román-Viñas B, Sánchez-Villegas A, Piscopo S, Serra-Majem L. The effect of the Mediterranean diet on hypertension: a systematic review and meta-analysis. J Nutr Educ Behav 2016;48(1):42–53.e1.
10. Kelly J, Khalesi S, Dickinson K, Hines S, Coombes JS, Todd AS. The effect of dietary sodium modification on blood pressure in adults with systolic blood pressure less than 140 mmHg: a systematic review. JBI Database System Rev Implement Rep 2016;14(6):196–237.
11. Suckling RJ, He FJ, Macgregor GA. Altered dietary salt intake for preventing and treating diabetic kidney disease. Cochrane Database Syst Rev 2010;12:CD006763.
12. Adler AJ, Taylor F, Martin N, Gottlieb S, Taylor RS, Ebrahim SA. Reduced dietary salt for the prevention of cardiovascular disease. Sao Paulo Med J 2015;133(3):280.
13. Yokoyama Y, Nishimura K, Barnard ND, Takegami M, Watanabe M, Sekikawa A, Okamura T, Miyamoto Y. Vegetarian diets and blood pressure: a meta-analysis. JAMA Intern Med 2014;174(4): 577–87.
14. Picasso MC, Lo-Tayraco JA, Ramos-Villanueva JM, Pasupuleti V, Hernandez AV. Effect of vegetarian diets on the presentation of metabolic syndrome or its components: a systematic review and meta-analysis. Clin Nutr 2019;38(3):1117–32.
15. Ndanuko RN, Tapsell LC, Charlton KE, Neale EP, Batterham MJ. Dietary patterns and blood pressure in adults: a systematic review and meta-analysis of randomized controlled trials. Adv Nutr 2016;7(1):76–89.
16. Viguiliouk E, Kendall CW, Kahleová H, Rahelić D, Salas-Salvadó J, Choo VL, Mejia SB, Stewart SE, Leiter LA, Jenkins DJ, et al. Effect of vegetarian dietary patterns on cardiometabolic risk factors in diabetes: a systematic review and meta-analysis of randomized controlled trials. Clin Nutr 2019;38(3):1133–45.
17. Schwingshackl L, Knuppel S, Schwedhelm C, Hoffmann G, Missbach B, Stelmach-Mardas M, Dietrich S, Eichelmann F, Kontopantelis E, Iqbal K, et al. Perspective: NutriGrade: a scoring system to assess and judge the meta-evidence of randomized controlled trials and cohort studies in nutrition research. Adv Nutr 2016;7(6): 994–1004.
18. Filippou CD, Tsioufis CP, Thomopoulos CG, Mihas CC, Dimitriadis KS, Sotiropoulou LI, Chrysochoou CA, Nihoyannopoulos PI, Tousoulis DM. Dietary Approaches to Stop Hypertension (DASH) diet and blood pressure reduction in adults with and without hypertension: a systematic review and meta-analysis of randomized controlled trials. Adv Nutr 2020;11(5):1150–60.
19. Huo R, Du T, Xu Y, Xu W, Chen X, Sun K, Yu X. Effects of Mediterranean-style diet on glycemic control, weight loss and cardiovascular risk factors among type 2 diabetes individuals: a meta-analysis. Eur J Clin Nutr 2015;69(11):1200–8.
20. Rees K, Takeda A, Martin N, Ellis L, Wijesekara D, Vepa A, Das A, Hartley L, Stranges S. Mediterranean-style diet for the primary and

secondary prevention of cardiovascular disease. Cochrane Database Syst Rev 2019;3(3):CD009825.
21. Lee KW, Loh HC, Ching SM, Devaraj NK, Hoo FK. Effects of vegetarian diets on blood pressure lowering: a systematic review with meta-analysis and trial sequential analysis. Nutrients 2020;12(6): 1604.
22. Lopez PD, Cativo EH, Atlas SA, Rosendorff C. The effect of vegan diets on blood pressure in adults: a meta-analysis of randomized controlled trials. Am J Med 2019;132(7):875–83.e7
23. Aburto NJ, Ziolkovska A, Hooper L, Elliott P, Cappuccio FP, Meerpohl JJ. Effect of lower sodium intake on health: systematic review and meta-analyses. BMJ 2013;346:f1326.
24. Garofalo C, Borrelli S, Provenzano M, De Stefano T, Vita C, Chiodini P, Minutolo R, De Nicola L, Conte G. Dietary salt restriction in chronic kidney disease: a meta-analysis of randomized clinical trials. Nutrients 2018;10(6):732.
25. Graudal NA, Hubeck-Graudal T, Jurgens G. Effects of low sodium diet versus high sodium diet on blood pressure, renin, aldosterone, catecholamines, cholesterol, and triglyceride. Cochrane Database Syst Rev 2017;4:CD004022.
26. He FJ, Li J, Macgregor GA. Effect of longer term modest salt reduction on blood pressure: Cochrane systematic review and meta-analysis of randomised trials. BMJ 2013;346:f1325.
27. Wang M, Moran AE, Liu J, Qi Y, Xie W, Tzong K, Zhao D. A meta-analysis of effect of dietary salt restriction on blood pressure in Chinese adults. Glob Heart 2015;10(4):291–9.e6.
28. Huang L, Trieu K, Yoshimura S, Neal B, Woodward M, Campbell NRC, Li Q, Lackland DT, Leung AA, Anderson CAM, et al. Effect of dose and duration of reduction in dietary sodium on blood pressure levels: systematic review and meta-analysis of randomised trials. BMJ (Clinical research ed) 2020;368:m315.
29. Jin A, Xie W, Wu Y. Effect of salt reduction interventions in lowering blood pressure in Chinese populations: a systematic review and meta-analysis of randomised controlled trials. BMJ Open 2020;10(2):e032941.
30. Evans CE, Greenwood DC, Threapleton DE, Gale CP, Cleghorn CL, Burley VJ. Glycemic index, glycemic load, and blood pressure: a systematic review and meta-analysis of randomized controlled trials. Am J Clin Nutr 2017;105(5):1176–90.
31. Clar C, Al-Khudairy L, Loveman E, Kelly SAM, Hartley L, Flowers N, Germanò R, Frost G, Rees K. Low glycaemic index diets for the prevention of cardiovascular disease. Cochrane Database of Syst Rev 2017;7(7):CD004467.
32. Reynolds A, Mann J, Cummings J, Winter N, Mete E, Te Morenga L. Carbohydrate quality and human health: a series of systematic reviews and meta-analyses. Lancet 2019;393(10170):434–45.
33. Bueno NB, de Melo IS, de Oliveira SL, da Rocha Ataide T. Very-low-carbohydrate ketogenic diet v. low-fat diet for long-term weight loss: a meta-analysis of randomised controlled trials. Br J Nutr 2013;110(7):1178–87.
34. Hu T, Mills KT, Yao L, Demanelis K, Eloustaz M, Yancy WS Jr, Kelly TN, He J, Bazzano LA. Effects of low-carbohydrate diets versus low-fat diets on metabolic risk factors: a meta-analysis of randomized controlled clinical trials. Am J Epidemiol 2012;176(Suppl 7): S44–54.
35. Mansoor N, Vinknes KJ, Veierod MB, Retterstol K. Effects of low-carbohydrate diets v. low-fat diets on body weight and cardiovascular risk factors: a meta-analysis of randomised controlled trials. Br J Nutr 2016;115(3):466–79.
36. Naude CE, Schoonees A, Senekal M, Young T, Garner P, Volmink J. Low carbohydrate versus isoenergetic balanced diets for reducing weight and cardiovascular risk: a systematic review and meta-analysis. PLoS One 2014;9(7):e100652.
37. Huntriss R, Campbell M, Bedwell C. The interpretation and effect of a low-carbohydrate diet in the management of type 2 diabetes: a systematic review and meta-analysis of randomised controlled trials. Eur J Clin Nutr 2018;72(3):311–25.
38. Korsmo-Haugen HK, Brurberg KG, Mann J, Aas AM. Carbohydrate quantity in the dietary management of type 2 diabetes: a systematic review and meta-analysis. Diabetes Obes Metab 2019;21(1):15–27.
39. Santos FL, Esteves SS, da Costa Pereira A, Yancy WS Jr, Nunes JPL. Systematic review and meta-analysis of clinical trials of the effects of low carbohydrate diets on cardiovascular risk factors. Obes Rev 2012;13(11):1048–66.
40. Dong T, Guo M, Zhang P, Sun G, Chen B. The effects of low-carbohydrate diets on cardiovascular risk factors: a meta-analysis. PLoS One 2020;15(1):e0225348.
41. Fechner E, Smeets E, Schrauwen P, Mensink RP. The effects of different degrees of carbohydrate restriction and carbohydrate replacement on cardiometabolic risk markers in humans—a systematic review and meta-analysis. Nutrients 2020;12(4):991.
42. Hooper L, Martin N, Abdelhamid A, Davey Smith G. Reduction in saturated fat intake for cardiovascular disease. Cochrane Database Syst Rev 2015;(6):CD011737.
43. Schwingshackl L, Hoffmann G. Comparison of the long-term effects of high-fat v. low-fat diet consumption on cardiometabolic risk factors in subjects with abnormal glucose metabolism: a systematic review and meta-analysis. Br J Nutr 2014;111(12):2047–58.
44. Hooper L, Summerbell CD, Thompson R, Sills D, Roberts FG, Moore HJ, Davey Smith G. Reduced or modified dietary fat for preventing cardiovascular disease. Cochrane Database of Syst Rev 2011;(7):CD002137.
45. Santesso N, Akl EA, Bianchi M, Mente A, Mustafa R, Heels-Ansdell D, Schünemann HJ. Effects of higher-versus lower-protein diets on health outcomes: a systematic review and meta-analysis. Eur J Clin Nutr 2012;66(7):780–8.
46. Tielemans S, Altorf-Van Der Kuil W, Engberink MF, Brink EJ, Van Baak MA, Bakker SJL, Geleijnse JM. Intake of total protein, plant protein and animal protein in relation to blood pressure: a meta-analysis of observational and intervention studies. J Hum Hypertens 2013;27(9):564–71.
47. Dong JY, Zhang ZL, Wang PY, Qin LQ. Effects of high-protein diets on body weight, glycaemic control, blood lipids and blood pressure in type 2 diabetes: meta-analysis of randomised controlled trials. Br J Nutr 2013;110(5):781–9.
48. Rebholz CM, Friedman EE, Powers LJ, Arroyave WD, He J, Kelly TN. Dietary protein intake and blood pressure: a meta-analysis of randomized controlled trials. Am J Epidemiol 2012;176(Suppl 7):S27–43.
49. Schwingshackl L, Hoffmann G. Long-term effects of low-fat diets either low or high in protein on cardiovascular and metabolic risk factors: a systematic review and meta-analysis. Nutr J 2013;12:48.
50. Zhao WT, Luo Y, Zhang Y, Zhou Y, Zhao TT. High protein diet is of benefit for patients with type 2 diabetes: an updated meta-analysis. Medicine (Baltimore) 2018;97(46):e13149.
51. Yu Z, Nan F, Wang LY, Jiang H, Chen W, Jiang Y. Effects of high-protein diet on glycemic control, insulin resistance and blood pressure in type 2 diabetes: a systematic review and meta-analysis of randomized controlled trials. Clin Nutr 2020;39(6):1724–34.
52. Ramezani-Jolfaie N, Mohammadi M, Salehi-Abargouei A. The effect of healthy Nordic diet on cardio-metabolic markers: a systematic review and meta-analysis of randomized controlled clinical trials. Eur J Nutr 2019;58(6):2159–74.
53. Manheimer EW, van Zuuren EJ, Fedorowicz Z, Pijl H. Paleolithic nutrition for metabolic syndrome: systematic review and meta-analysis. Am J Clin Nutr 2015;102(4):922–32.
54. Ghaedi E, Mohammadi M, Mohammadi H, Ramezani-Jolfaie N, Malekzadeh J, Hosseinzadeh M, Salehi-Abargouei A. Effects of a Paleolithic diet on cardiovascular disease risk factors: a systematic review and meta-analysis of randomized controlled trials. Adv Nutr 2019;10(4):634–46.
55. Chiavaroli L, Nishi SK, Khan TA, Braunstein CR, Glenn AJ, Mejia SB, Rahelić D, Kahleová H, Salas-Salvadó J, Jenkins DJA, et al. Portfolio dietary pattern and cardiovascular disease: a systematic review and meta-analysis of controlled trials. Prog Cardiovas Dis 2018;61(1):43–53.
56. Jayalath VH, De Souza RJ, Sievenpiper JL, Ha V, Chiavaroli L, Mirrahimi A, Di Buono M, Bernstein AM, Leiter LA, Kris-Etherton PM, et al. Effect of dietary pulses on blood pressure: a systematic review and meta-analysis of controlled feeding trials. Am J Hypertens 2014;27(1):56–64.
57. Cordain L, Eaton SB, Sebastian A, Mann N, Lindeberg S, Watkins BA, O'Keefe JH, Brand-Miller J. Origins and evolution of the Western diet: health implications for the 21st century. Am J Clin Nutr 2005;81(2):341–54.
58. Schwingshackl L, Chaimani A, Schwedhelm C, Toledo E, Punsch M, Hoffmann G, Boeing H. Comparative effects of different dietary approaches on blood pressure in hypertensive and pre-hypertensive

patients: a systematic review and network meta-analysis. Crit Rev Food Sci Nutr 2019;59(16):2674–87.
59. Brader L, Uusitupa M, Dragsted LO, Hermansen K. Effects of an isocaloric healthy Nordic diet on ambulatory blood pressure in metabolic syndrome: a randomized SYSDIET sub-study. Eur J Clin Nutr 2014;68(1):57–63.
60. Lewington S, Clarke R, Qizilbash N, Peto R, Collins R. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. Lancet 2002;360(9349):1903–13.
61. Cook NR, Cohen J, Hebert PR, Taylor JO, Hennekens CH. Implications of small reductions in diastolic blood pressure for primary prevention. Arch Intern Med 1995;155(7):701–9.
62. Tuttolomondo A, Simonetta I, Daidone M, Mogavero A, Ortello A, Pinto A. Metabolic and vascular effect of the Mediterranean diet. Int J Mol Sci 2019;20(19):4716.
63. Veronese N, Solmi M, Caruso MG, Giannelli G, Osella AR, Evangelou E, Maggi S, Fontana L, Stubbs B, Tzoulaki I. Dietary fiber and health outcomes: an umbrella review of systematic reviews and meta-analyses. Am J Clin Nutr 2018;107(3):436–44.
64. Liu AG, Ford NA, Hu FB, Zelman KM, Mozaffarian D, Kris-Etherton PM. A healthy approach to dietary fats: understanding the science and taking action to reduce consumer confusion. Nutr J 2017;16(1): 53.
65. Prentice RL, Aragaki AK, Howard BV, Chlebowski RT, Thomson CA, Van Horn L, Tinker LF, Manson JE, Anderson GL, Kuller LE, et al. Low-fat dietary pattern among postmenopausal women influences long-term cancer, cardiovascular disease, and diabetes outcomes. J Nutr 2019;149(9):1565–74.
66. Malaeb S, Bakker C, Chow LS, Bantle AE. High-protein diets for treatment of type 2 diabetes mellitus: a systematic review. Adv Nutr 2019;10(4):621–33.
67. Virtanen HEK, Voutilainen S, Koskinen TT, Mursu J, Kokko P, Ylilauri MPT, Tuomainen TP, Salonen JT, Virtanen JK. Dietary proteins and protein sources and risk of death: the Kuopio Ischaemic Heart Disease Risk Factor Study. Am J Clin Nutr 2019;109(5):1462–71.
68. Fan J, Song Y, Wang Y, Hui R, Zhang W. Dietary glycemic index, glycemic load, and risk of coronary heart disease, stroke, and stroke mortality: a systematic review with meta-analysis. PLoS One 2012;7(12):e52182.