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The blood pressure control effect of the sodium-restricted dietary approaches to stop hypertension diet: a systematic review

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Abstract

The Dietary Approaches to Stop Hypertension (DASH) diet is highly effective in controlling blood pressure (BP). Although Na restriction is not a primary focus within the DASH diet, it is recommended that it be added to control BP. Therefore, we aimed to systematically review the characteristics and BP-lowering effects of Na-restricted DASH diet interventions. We searched thirteen databases, namely, MEDLINE, Embase, Cochrane Central Register of Controlled Trials, KoreaMed, KISS, KMbase, RISS, CINAHL, Scopus, ClinicalTrials.gov, Grey Literature Report, OpenGrey and PQDT Global, for articles published through May 2023. The randomised controlled trials assessing the BP-lowering effect of the Na-restricted DASH diet in adults aged 18 years and older were included. The study protocol was registered in the PROSPERO registry (CRD42023409996). The risk of bias in the included studies was also assessed. Nine articles were included in this review. Interventions were categorised into three types: feeding, provision and education, and the study results were compared by intervention type. BP was significantly reduced in two of the three feeding studies, one of the three provisional studies and none of the educational studies. In eight studies, effect sizes varied among both systolic BP (–7·7 to −2·4) and diastolic BP (–8·3 to 0·1). Six studies showed an overall high risk of bias. In conclusion, Na-restricted DASH may have beneficial effects on BP control. Additionally, compared with control interventions, feeding interventions appeared to have a greater BP-lowering effect. Further high-quality studies are needed to improve the quality of the evidence.

Keywords: **Blood pressure: Dash diet: Hypertension: Sodium-restricted diet: Systematic review**

Introduction

The WHO reports that approximately 1·3 billion people aged 30–79 years have hypertension[1]. Hypertension is a major risk factor for CVD and early death[1,2], and thus, its prevention and control are vital. Diet is a crucial, modifiable risk factor for hypertension[3]. In 1997, the National Heart, Lung, and Blood Institute in the USA developed the Dietary Approaches to Stop Hypertension (DASH) diet that was aimed at reducing blood pressure (BP)[4]. Many previous studies have confirmed the BP-controlling effect of the DASH diet, and it has been proven to be one of the most effective diets for hypertension control[5].

The DASH diet promotes increased potassium intake through higher consumption of fruits and vegetables[6]. Additionally, it promotes enhanced Mg, Ca and dietary fibre consumption, as these are inversely associated with high BP[4]. Although Na plays a critical role in BP regulation by increasing water retention to maintain homeostasis, consequently leading to an increase in BP[7], the original DASH diet did not explicitly include Na restriction[4]. Instead, it expects the potassium in vegetables and fruits to promote Na excretion[8].

However, individuals with dental issues[9] or those from lower socio-economic backgrounds[10] may face challenges in consuming the recommended quantities of vegetables and fruits. In such scenarios, the effectiveness of potassium in Na control might be compromised. In addition, Na intake is recommended to be limited to ≤2300 mg or 1500 mg when following the DASH diet[11,12]. Therefore, integrating Na restriction with the DASH diet could be beneficial in managing BP, especially among older adults, who tend to consume more salt owing to diminished taste sensitivity[13]. Specifically, a Na-restricted DASH diet might have a more pronounced impact on BP management in hypertension patients.

The BP control effects of both the DASH diet and Na restriction have been systematically and independently reviewed[5,14]. However, to our best knowledge, there has been no systematic attempt to review and identify interventions that

Abbreviations: BP, blood pressure; DASH, dietary approaches to stop hypertension; DBP, diastolic blood pressure; SBP, systolic blood pressure.

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combine Na restriction with the DASH diet for BP control. Thus, this study aimed to address this gap by systematically reviewing and elucidating the characteristics and BP control effects of interventions that combine a Na-restricted DASH diet.

Methods

This systematic review was conducted following the Cochrane Handbook for Systematic Reviews of Interventions[15]. This study was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guideline[16] and the Synthesis Without Meta-Analysis guideline[17]. The study protocol was registered with PROSPERO (ID: CRD42023409996).

Search strategy and study selection

The following nine databases were searched between April and May 2023: MEDLINE, Embase, Cochrane Central Register of Controlled Trials, CINAHL, Scopus, KoreaMed, KISS, KMbase and RISS. ClinicalTrials. Gov, Grey Literature Report, OpenGrey and PQDT Global were also searched to include grey literature. The search strategy was established using the Boolean operators 'OR' and 'AND' to combine keywords related to 'dietary approaches to stop hypertension' and 'sodium restriction'. Index terms of the databases and free-text terms were used to establish the search strategy (online Supplementary Table 1), which a librarian reviewed before the search. We limited the language of the studies to English and Korean without limiting the publication year. The Population, Intervention, Comparison, Outcome and Study (PICOS) frames used are presented in Table 1.

EndNote 20 (Clarivate Analytics) was used to import studies and remove duplicates. The studies were independently selected by two researchers (SK and HJ) based on the eligibility criteria and PICOS. Disagreements between the researchers were resolved through discussions to reach a consensus. The initial screening included screening the titles and abstracts of the articles for eligibility. Full articles were retrieved and read to evaluate their eligibility. The eligibility criteria of this study were as follows: (1) randomised controlled trials evaluating the BP-controlling effect of the Na-restricted DASH diet in adults (age ≥ 18 years), except in pregnant women as gestational hypertension has a different pathophysiology from general hypertension[18], and (2) studies for which the full article can be retrieved.

Data extraction and analysis

Two researchers (SK and HJ) autonomously extracted the data from the included studies using a data extraction form. Disagreements were resolved through discussions and joint reviews of the original articles. The extracted data included publication characteristics (authors, journals and year of publication), study characteristics (country, sample size, age, sex, race and hypertension status), intervention content (amount of Na restriction, details of the intervention, intervention setting and duration of intervention) and outcome (BP before and after intervention). Hypertension status was categorised as 'elevated BP' or 'hypertension' according to the 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline[19]. Elevated BP was defined as systolic blood pressure (SBP) ranging from 120 mmHg to 129 mmHg and diastolic blood pressure (DBP) under 80 mmHg[19]. However, hypertension was defined as SBP ≥ 130 mmHg or DBP ≥ 80 mmHg[19].

Table 1. The PICOS of the study

PICOS	Description
Population	Adults aged over 18 years
Intervention	Sodium-restricted DASH diet
Comparison	Interventions other than the Na-restricted DASH diet
Outcome	Blood pressure
Study type	Randomised controlled trials

DASH, dietary approaches to stop hypertension.

When the BP was measured multiple times, we included the results obtained in the clinical setting in the analysis to consider the accuracy of the results. A narrative summary of the included studies was created based on the extracted data. Considering that the intervention types differed among the included studies, the results of the studies were also compared based on the intervention types. Nevertheless, if there were more than two groups in the included studies, we combined the groups that applied the Na-restricted DASH diet as the intervention group and the groups without the Na-restricted DASH diet as the comparator for the analysis. Furthermore, the effect sizes of the included studies on BP control were calculated using the mean difference, and a box-and-whisker plot was drawn. Additionally, evidence certainty was evaluated using the Grading of Recommendations, Assessment, Development and Evaluations approach through GRADEpro GDT (McMaster University and Evidence Prime).

Risk of bias assessment

The risk of bias in each included study was independently evaluated by two researchers (SK and HJ) using the Risk of Bias 2·0[20]. Researchers followed the Risk of Bias 2·0 algorithm to assess the risk of bias by answering the questions for five domains (bias arising from the randomisation process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in the measurement of the outcome and bias in the selection of the reported result)[20]. Each question was answered by 'yes (Y)', 'probably yes (PY)', 'no (N)', 'probably no (PN)' and 'no information (NI)'. Any disagreements in the decision for each question between researchers were addressed through discussion. Additionally, each domain was rated as 'low risk of bias', 'some concerns' and 'high risk of bias', followed by a rating of the overall risk of bias[20].

Results

Selected studies

A total of 4819 articles were identified through a comprehensive search, with 2793 found to be duplicates. After reviewing the

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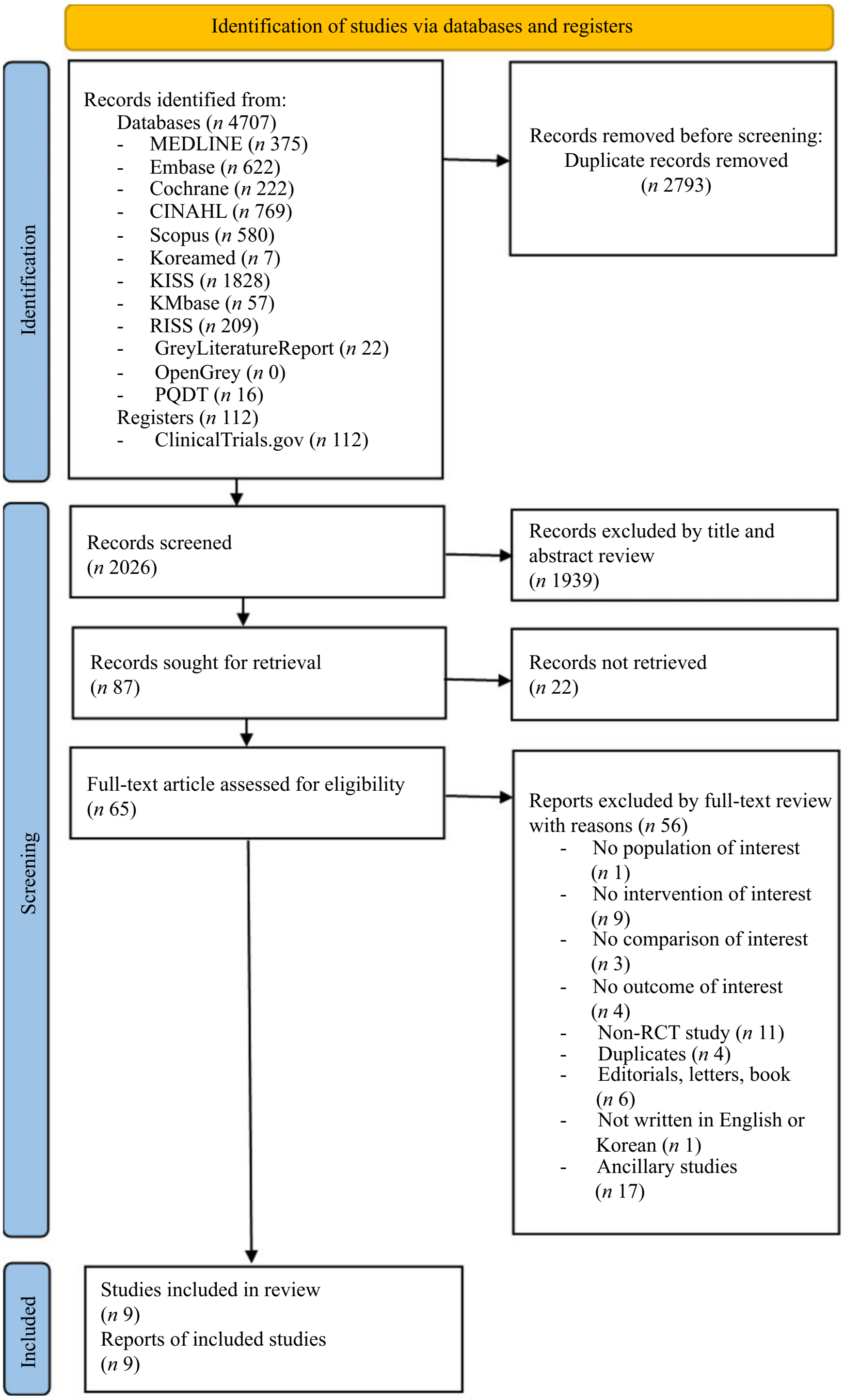

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analysis 2020 flow diagram.

titles and abstracts of the remaining 2026 articles, 1939 articles were excluded because of irrelevance. Among the remaining eighty-seven articles, twenty-two were further excluded due to the unavailability of the full articles. A full-text review was conducted on the remaining sixty-five articles, and fifty-six articles were excluded due to unrelatedness. Ultimately, nine studies[21–29] fulfilled our inclusion criteria and were included in the systematic review (Fig. 1).

General characteristics of the included studies

The included studies were published between 2001 and 2022. Four studies were conducted in the USA, and five studies were conducted in Australia, Canada, Greece, Japan and Pakistan. The number of participants ranged from 25 to 1700, with a total of 3412. However, 398 participants were excluded from the final analysis owing to loss to follow-up or compliance issues. The average participant age was 52·1 years. One study included only menopausal females[25], while another included males and females. Among the nine studies, only three included Asians[24,27,29], and three studies included diverse races[21,23,26]. Furthermore, one study targeted African Americans[28], and the last two studies did not identify the race of the study participants[22,25]. All studies included participants with hypertension or elevated BP (Table 2).

Intervention characteristics of the included studies

The amount of Na restriction varied among the nine studies, ranging from approximately 1150 to 3100 mg (Table 3). Notably, three studies employed multiple standards of Na restriction[22,26,29]. In one study, three different Na restriction amounts were applied to all participants in random order during the intervention[26]. In contrast, another study adjusted three different Na restriction amounts based on the participant's age[29]. However, one study did not identify how the two different amounts of Na restriction were applied[22].

We classified the Na-restricted DASH diet interventions in the included studies into three categories: feeding, menu or food item provision and education. Three studies conducted feeding interventions in which the researchers provided meals to the participants[23,25,27], while the other three provided weekly menus or food items to the participants[22,24,25]. Additionally, another three offered lectures and counselling to the participants[21,28,29]. The intervention duration ranged from 5 weeks to 6 months.

Outcome characteristics of the included studies

BP was the outcome variable in the included studies. The frequency and methods used to measure BP varied among the studies. All studies conducted pre- and post-intervention BP measurements, while five studies also assessed BP during the intervention at least once[21,22,25,26,28]. Except for one study that did not specify the setting of BP measurement[28], the remaining eight studies measured BP in a clinical setting using manual or digital sphygmomanometers. The methods of BP measurement are detailed in online Supplementary Table 2. One study additionally measured 24-h ambulatory BP[23]. Furthermore, two studies also asked their participants to measure BP at home[25,27]. A single study conducted a follow-up BP measurement 4 months post-intervention[27].

All intervention groups exhibited a decrease in BP following the intervention. However, only three studies revealed significantly lower BP in the intervention group than in the control group[24,26,27] (Table 3). The analysis of study outcomes relative to the type of intervention was conducted as follows. Among the three feeding studies, two studies demonstrated significantly lower BP compared with the control group[26,27]. In the study by Sacks *et al.*[26], the implementation of a DASH diet coupled with a 50 mmol Na restriction led to a reduction in both SBP and DBP, surpassing the control group that adhered to an American diet with a 150 mmol Na limitation[26]. Umemoto *et al.*[27] explored two distinct intervention groups: the Japanese cuisine-based DASH 1 group and the Japanese cuisine-based DASH 2 group, which varied in the frequency of DASH diet application. Both intervention groups exhibited a more pronounced BP reduction than the control group[27].

In the context of menu or food item provision studies, Naseem *et al.*[24] observed a greater SBP decrease in the intervention group, whereas Nowson *et al.*[25] found no significant differential effect. Kirpizidis *et al.*[22] did not clarify the differences among groups. Furthermore, two educational intervention studies failed to show significant differences between the intervention and control groups[28,29]. Appel *et al.*[21] implemented an educational intervention and involved three distinct groups: the advice-only group, the established group implementing lifestyle changes, including Na restriction, and the established + DASH group, which combined lifestyle changes with a DASH diet. The established + DASH group experienced a higher reduction in both SBP and DBP than did the advice-only group[21]. However, the difference was not significant when compared with the established group[21].

The effect sizes varied across the included studies. Notably, calculating the mean difference in BP by Sacks *et al.*[26] was not feasible because the participants in their study had different orders of Na restriction. Consequently, this study was excluded from effect size calculations. The box-and-whisker plot constructed based on the effect sizes of the remaining eight studies is shown in Fig. 2. The effect size of the SBP ranged from −7·70 to −2·40 (median: −3·70; 95 % CI −5·76, −2·92). The effect size of the DBP ranged from −8·30 to 0·10 (median: −2·95; 95 % CI −5·60, −1·66).

Risk of bias

For the risk of bias assessment using the Risk of Bias 2·0, six out of nine included studies showed a high risk of bias[21,24–26,29] (Fig. 3). Additionally, the remaining three studies had some concerns regarding the risk of bias[22,23,27]. Particularly, the selection of reported results showed the greatest risk of bias.

Evidence certainty

The results of the evidence certainty assessment according to the Grading of Recommendations, Assessment, Development and Evaluations approach are presented in Table 4. Owing to the generally high risk of bias among the included studies, the certainty of the evidence was low for SBP and DBP.

Discussion

We conducted a systematic review to comprehensively examine the characteristics and BP-controlling effects of Na-restricted DASH dietary interventions. Despite the BP reduction observed in all the intervention groups after applying the Na-restricted DASH diet, feeding interventions showed a greater effect on BP control than the control interventions. Our findings demonstrated that feeding interventions were more effective in controlling BP than provisional or educational interventions. This result might be because it was easier and more convenient for participants to comply with the feeding interventions than provisional or educational interventions. Although the participants in provisional or educational studies needed to prepare their meals, those in feeding studies had their meals provided by researchers. Therefore, participants in the feeding studies did not require extra time or effort to prepare meals or purchase food

Table 2. Publication and general characteristics of the included studies (*n* 9)

Author	Publication year	Country	Population	I/C	Mean age	SD	Sex	Race	Hypertension status
Appel *et al.* [16]	2003	USA	810	E 268/ E + DASH 269/ 273	50·0	8·9	M 38 % F 62 %	34 % Blacks 63 % Whites 3 % Others	Elevated BP Hypertension
Kirpizidis *et al.* [17]	2005	Greece	201	99/102	I: 54·1 C: 53·5	7·7 8·4	M 68 % F 32 %	NI	Hypertension
Miller *et al.* [18]	2002	USA	45	22/23	54	9	M 38 % F 62 %	62 % Blacks	Hypertension
Naseem *et al.* [19]	2016	Pakistan	1700	950/750	I: 52·3 C: 54·4	9·1 93·4	M 51 % F 49 %	100 % Asians	Hypertension
Nowson *et al.* [20]	2009	Australia	111	53/58	I: 60·0 C: 58·4	0·7 0·7	F 100 %	NI	Elevated BP Hypertension
Sacks *et al.* [21]	2001	USA	412	208/204	I: 47 Cl: 49	10 10	M 43 % F 57 %	56 % Blacks 40 % Whites 4 % Asians/others	Elevated BP Hypertension
Umemoto *et al.* [22]	2022	Japan	48	J1 16/J2 16/16	J1:51·9 J2:50·0 C: 48·6	6·2 9·5 7·6	M 55 % F 45 %	100 % Asians	Hypertension
Whitt-Glover *et al.* [23]	2013	USA	25	14/11	50·7	7·9	M 12 % F 88 %	100 % Blacks	Elevated BP Hypertension
Zou *et al.* [24]	2017	Canada	60	30/30	62·0	11·2	M 48 % F 52 %	100 % Asians	Hypertension

I, intervention; C, control; SD, standard deviation; E, established; DASH, dietary approaches to stop hypertension; M, male; F, female; BP, blood pressure; NI, no information; J, J-DASH (Japanese cuisine-based DASH).

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Table 3. Summary of intervention and the result of the included studies (*n* 9)

Author	Restricted Na amount	Intervention content	Comparison intervention content	Setting	Intervention period	Effect size SBP	Effect size DBP	Effect of the intervention
Feeding								
Miller *et al.* [18]	100 mmol	Supply of meals following the Na-restricted DASH diet with aerobic exercise	Nutrition and lifestyle counselling	At the clinic site and at home	9 weeks	–7·40	–5·70	No impact
Sacks *et al.* [21]	50, 100, 150 mmol	Supply of meals following the Na-restricted DASH diet with three different Na levels in a random order for 30 consecutive days	Supply of meals following the typical American diet with three Na levels in a random order for 30 consecutive days	At the clinic site & at home	90 days	–	–	Favourable both on SBP and DBP
Umemoto *et al.* [22]	8 g of salt	J1: Supply of five meals without a fish hamburger patty on weekdays, accompanied by two 1-h lifestyle alteration lectures J2: Supply of ten meals, including a fish hamburger patty on weekdays, accompanied by two 1-h lifestyle alteration lectures	Two 1-h lifestyle alteration lectures	At home	2 months	–3·60*	–6·10*	Favourable on SBP
Menu or food items provision								
Kirpizidis *et al.* [17]	1500 or 2400 mg	Provision of weekly menu following the Na-restricted DASH diet with 8 mg candesartan	8 mg candesartan	At home	16 weeks	–4·00	–3·50	NI
Naseem *et al.* [19]	1500 mg	Provision of a menu adhering to the Na-restricted DASH diet	Routine diet	At home	5 weeks	–2·40	0·10	Favourable on SBP
Nowson *et al.* [20]	60–70 mmol	Weekly provisions of food items adhering to the Na-restricted DASH diet	Weekly provisions of food items adhering to the low-fat diet	At home	14 weeks	–2·90	–1·20	No impact
Education								
Appel *et al.* [16]	100 mEq	E: Fourteen meetings and four individual counselling sessions on weight loss, enhancing physical activity and reducing Na and alcohol intake E + DASH: E intervention combined with instruction and counselling on the DASH diet	One 30-min individual session	NI	6 months	–2·90†	–1·90†	Inconsistent
Whitt-Glover *et al.* [23]	2300 mg	Nine group sessions and two individual sessions on following the Na-restricted DASH diet	One individual counselling session and booklets on BP control following DASH diet	NI	12 Weeks	–7·70	–8·30	No impact
Zou *et al.* [24]	1200–1500 mg	Offering hypertension education booklet, support to see an HCP and healthcare access info, accompanied with intervention manual and poster with two 2-h classroom sessions and one 20-min booster phone call	Offering hypertension education booklet, support to see an HCP and healthcare access info	At a community centre	8 weeks	–3·80	–2·40	No impact

SBP, systolic blood pressure; DBP, diastolic blood pressure; DASH, dietary approaches to stop hypertension; J, J-DASH (Japanese cuisine-based DASH); NI, no information; E, stablished; HCP, healthcare provider.
* The effect sizes are calculated by comparing the control group and the combined group of J-DASH 1 and J-DASH 2 groups.
† The effect sizes are calculated by comparing the established + DASH group and the combined group of the control and established groups.

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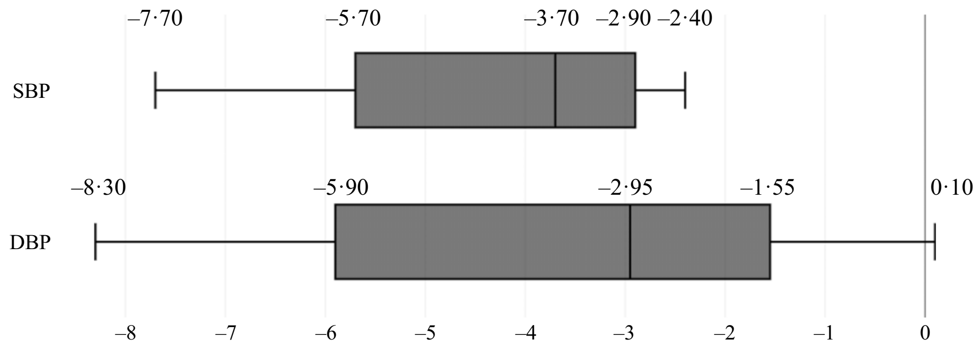

Fig. 2. Box-and-whisker plot of the effect sizes.

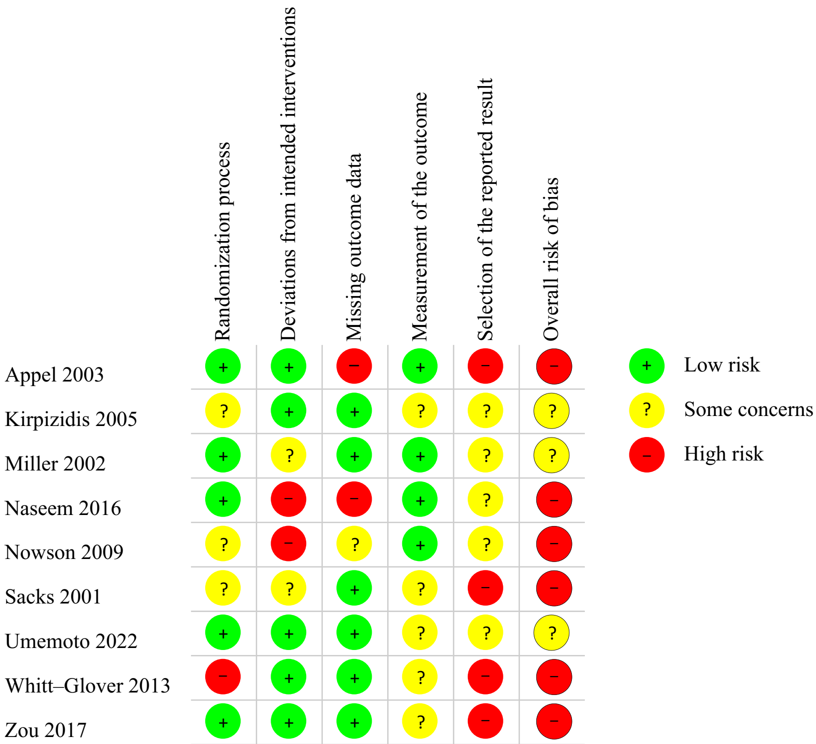

Fig. 3. Summary of the risk of bias of included studies.

items from a Na-restricted DASH diet, potentially leading to higher adherence. Given that high adherence to the DASH diet correlates directly with BP reduction[30], high adherence to the Na-restricted DASH diet may also correlate directly with BP reduction.

Furthermore, the precise delivery of nutrients in feeding studies could contribute to the greater effectiveness of BP reduction. This aligns with a previous study where participants in a feeding study had better-quality meals and the amount they ate was more accurate[31]. Given that researchers prepare meals for participants in feeding interventions, food and Na could be delivered in the amount planned by the researchers. Conversely, the amount of nutrients consumed in provisional or educational studies could be inaccurate. The intervention duration (2–3 months) may also contribute to the greater BP control effect of the feeding interventions. In intervention studies, delivering an intervention for more than 8 weeks is recommended to avoid novelty effects[32]. However, if the intervention period is too long, the dropout rate and the risk of being affected by other distributing factors may likely increase[33,34].

Our results show that only one of the three provisional studies showed a significant BP reduction when compared with the values of the control group[24]. The inconsistent results of the included provisional studies may be attributed to improper control interventions and diverse study designs. Naseem *et al.*[24], who reported a significant reduction in SBP, encouraged the control group to maintain their usual diet. Conversely, Nowson *et al.*[25] offered low-fat diet food items to the control group and found no difference in BP reduction between groups. This could be because a low-fat diet also decreases BP[35], although the BP of the intervention group was considerably decreased. Kirpizidis *et al.*[22] had a different study

Table 4. Grading of Recommendations, Assessment, Development and Evaluations (GRADE) certainty assessment

Outcomes	Number of participants (studies)	Certainty of the evidence	Impact
SBP follow-up: range, 5 weeks to 6 months	3412 (9 RCT)	⨁⨁○○ Low*	Three studies showed reduction in SBP, five studies did not show any difference, and one study did not report the result
DBP follow-up: range, 5 weeks to 6 months	3412 (9 RCT)	⨁⨁○○ Low*	One study showed a reduction in DBP, seven studies did not show difference, and one study did not report the result

SBP, systolic blood pressure; RCT, randomised controlled trials; DBP, diastolic blood pressure.
GRADE Working Group grades of evidence. High certainty: We are very confident that the true effect lies close to that of the estimate of the effect. **Moderate certainty:** We are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different. **Low certainty:** Our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect. **Very low certainty:** We have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.
* Overall, six of nine studies are assessed as having a high risk of bias. The other three studies had some concerns for the risk of bias.

design. However, they did not compare the intervention and control groups after the intervention and instead measured the changes in BP in both groups. They reported that both intervention and control groups showed a significant reduction in BP after the interventions.

In contrast, the educational interventions included in our study did not show an apparent BP control effect. Previous studies have reported that personal factors (e.g. attitude towards diet) and environmental factors (e.g. the accessibility or affordability of food items) are crucial in changing dietary behaviour[36]. The lack of significant reduction in BP in the studies by Appel *et al.*[21] and Zou *et al.*[29] may be attributed to their exclusive focus on personal factors in the interventions. However, another study did not show a BP-lowering effect, although it included environmental factors in the intervention by providing information about budgeting and grocery shopping[28]. We do not know why Whitt-Glover *et al.*[28], who included both personal and environmental factors, did not find a positive effect on reducing BP. Education alone might not have been sufficient to change dietary behaviour.

Although our study results indicated that the Na-restricted DASH diet might lower BP, previous systematic reviews reported differing results[14,37]. These discrepancies may be attributed to several factors. First, in Filippou *et al.*[14], ten of the twenty-three studies were of low quality. Additionally, in Guo *et al.*[37], two of the five studies exhibited a high risk of bias, while the remaining three also raised some concerns about bias. Therefore, the low quality of the included studies and the risk of bias may have contributed to the disparate findings. Second, intervention types might have influenced the result. Filippou *et al.*[14] did not report the intervention types of the included studies. Conversely, Guo *et al.*[37] included only one feeding study in the analysis. Considering our finding that the Na-restricted DASH diet demonstrated a conspicuous BP-controlling effect in feeding studies, this discrepancy in results might be due to the limited representation of feeding studies in the previous analyses.

Regrettably, only one long-term study has been identified[27]. It is crucial to ascertain if the impact of an intervention endures beyond the intervention period rather than merely the immediate effect post-intervention[38]. A prior study demonstrated that the DASH diet sustained its BP control effect for up to 8 months following the intervention[39]. In addition, a study that implemented a mindfulness and DASH diet intervention showed a greater systolic BP reduction in the intervention group than in the non-hypertensive educational group even a month after the intervention[40]. Additionally, Juraschek *et al.*[41] observed that a gradual reduction in Na intake consistently lowered BP over a 4-week period. Given these findings, implementing follow-up BP measurements at least once after a month of interventions could have confirmed the BP control efficacy of the Na-restricted DASH diet rather than relying solely on assessments conducted immediately post-intervention.

There were some limitations in our systematic review. First, six of the nine studies showed a high risk of bias[21,24–26,29], and the other three studies similarly showed some concerns[22,23,27]. Therefore, the overall high risk of bias served as a critical factor preventing the performance of a meta-analysis. Additionally, it was a key determinant in establishing the certainty of evidence as 'low' in the Grading of Recommendations, Assessment, Development and Evaluations certainty assessment. Therefore, the results should be interpreted with caution. Second, we could not conduct a meta-analysis because of the high heterogeneity among the included studies. A meta-analysis presupposes homogeneity of studies regarding participants, interventions, comparators and results[15]. Nevertheless, the studies included in our study varied in intervention type, duration, restricted Na intake and comparators. Therefore, we could not confirm the presuppositions of the meta-analysis. Third, we limited the publication language to English and Korean. Therefore, there is a possibility that we might have omitted pertinent studies. Therefore, our study findings should be interpreted and applied with caution.

Although there are limitations to the study results, to the best of our knowledge, this is the first attempt to systematically review the characteristics of a Na-restricted DASH diet and its BP-lowering effect. Further high-quality research on the Na-restricted DASH diet is required to address the limitations of the included studies. First, we suggest mitigating the high risk of bias by thoroughly reporting all measured outcomes to improve the quality of future research. Second, we recommend that future researchers consider including a control group with the usual diet when implementing other BP-lowering diets in the control group. This approach may better elucidate the BP-lowering effect of the Na-restricted DASH diet. Once sufficient high-

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quality research has been accumulated, a meta-analysis should be conducted to integrate the BP-lowering effects of a Na-restricted DASH diet. Third, participants in the included studies had hypertension or elevated BP. Given that the DASH diet has a preventive effect on hypertension[42], it is also necessary to test the preventive effect of a Na-restricted DASH diet. Therefore, we recommend including normotensive participants in future studies. Lastly, for future research on the Na-restricted DASH diet, follow-up BP measurements should be conducted after the intervention to assess its long-term effect on BP. Considering that feeding interventions proved more effective than other types of interventions, adopting a Na-restricted DASH diet may be beneficial under specific circumstances for lowering BP, particularly in hypertension patients in hospitals or nursing homes.

Conclusion

The findings indicate that the Na-restricted DASH diet has a more significant BP-lowering effect, particularly in feeding studies, than provisional or educational interventions. Nonetheless, the substantial risk of bias and heterogeneity in the included studies prevented conducting a meta-analysis. Furthermore, our findings have low reliability owing to the generally high risk of bias. However, this systematic review aimed to delineate the attributes of the Na-restricted DASH diet and its effects on BP reduction, striving to provide the best evidence through systematic review.

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S. K.: formulating the research questions, designing the study, carrying out the study, analysing the data, interpreting the findings and writing the article. H. N. J.: designing the study, carrying out the study and writing the article. S. C.-K.: formulating the research questions and writing the article.

The authors declare that there are no conflicts of interest.

Data described in this manuscript are available in the included articles. This article is a revision of the first author's doctoral dissertation from Seoul National University.

Supplementary material

For supplementary materials referred to in this article, please visit https://doi.org/10.1017/S000711452400103X.

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