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Effects of Sodium Reduction and the DASH Diet in Relation to Baseline Blood Pressure

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ABSTRACT

BACKGROUND Both sodium reduction and the DASH (Dietary Approaches to Stop Hypertension) diet, a diet rich in fruits, vegetables, and low-fat dairy products, and reduced in saturated fat and cholesterol, lower blood pressure. The separate and combined effects of these dietary interventions by baseline blood pressure (BP) has not been reported.

OBJECTIVES The authors compared the effects of low versus high sodium, DASH versus control, and both (low sodium-DASH vs. high sodium-control diets) on systolic BP (SBP) by baseline BP.

METHODS In the DASH-Sodium (Dietary Patterns, Sodium Intake and Blood Pressure) trial, adults with pre- or stage 1 hypertension and not using antihypertensive medications, were randomized to either DASH or a control diet. On either diet, participants were fed each of 3 sodium levels (50, 100, and 150 mmol/day at 2,100 kcal) in random order over 4 weeks separated by 5-day breaks. Strata of baseline SBP were <130, 130 to 139, 140 to 149, and ≥150 mm Hg.

RESULTS Of 412 participants, 57% were women, and 57% were black; mean age was 48 years, and mean SBP/diastolic BP was 135/86 mm Hg. In the context of the control diet, reducing sodium (from high to low) was associated with mean SBP differences of −3.20, −8.56, −8.99, and −7.04 mm Hg across the respective baseline SBP strata listed (p for trend = 0.004). In the context of high sodium, consuming the DASH compared with the control diet was associated with mean SBP differences of −4.5, −4.3, −4.7, and −10.6 mm Hg, respectively (p for trend = 0.66). The combined effects of the low sodium-DASH diet versus the high sodium-control diet on SBP were −5.3, −7.5, −9.7, and −20.8 mm Hg, respectively (p for trend < 0.001).

CONCLUSIONS The combination of reduced sodium intake and the DASH diet lowered SBP throughout the range of pre- and stage 1 hypertension, with progressively greater reductions at higher levels of baseline SBP. SBP reductions in adults with the highest levels of SBP (≥150 mm Hg) were striking and reinforce the importance of both sodium reduction and the DASH diet in this high-risk group. Further research is needed to determine the effects of these interventions among adults with SBP ≥160 mm Hg. (Dietary Patterns, Sodium Intake and Blood Pressure [DASH-Sodium]; NCT00000608) (J Am Coll Cardiol 2017;■:■–■) © 2017 by the American College of Cardiology Foundation.

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ABBREVIATIONS AND ACRONYMS

BMI = body mass index

BP = blood pressure

CI = confidence interval

DBP = diastolic blood pressure

SBP = systolic blood pressure

Consuming a healthful diet is an important approach to lower blood pressure (BP). This was shown definitively in the DASH (Dietary Approaches to Stop Hypertension) trial, which demonstrated that consuming a diet rich in fruits, vegetables, and low-fat dairy products, and reduced in saturated fat and cholesterol lowered systolic blood pressure (SBP) and diastolic blood pressure (DBP) (1). Subsequently, the DASH-Sodium (Dietary Patterns, Sodium Intake and Blood Pressure) trial confirmed that the DASH diet lowered SBP and DBP (2). In addition, this trial demonstrated that reducing sodium had a significant impact on BP independently of the effects of the DASH diet. On the basis of these studies, both of these strategies are recommended for all adults with pre-hypertension or stage 1 hypertension, as well as the general population (3). The DASH-Sodium trial has previously reported the effects of these interventions, alone and combined, overall and separately, in pre-hypertensive and hypertensive individuals. However, whether the effects of the DASH diet or sodium reduction differ by level of BP has not been reported. Furthermore, using just baseline hypertension status (yes/no) underestimates the full effect of these interventions on either SBP or DBP. In order to determine whether the effects from the DASH diet or sodium reduction differ by hypertension severity, it is necessary to document the effects of these interventions by strata of absolute level of baseline SBP or DBP.

We conducted this secondary analysis of the DASH-Sodium trial to determine the BP-lowering effects of: 1) sodium reduction alone; 2) the DASH diet alone in strata of high or low sodium; and 3) both interventions across strata of baseline SBP or DBP. We hypothesized that the effects of either or both lifestyle interventions would be greater among participants with a higher baseline BP. We were especially interested in the effects of these interventions among those with the highest level of baseline BP.

METHODS

The DASH-Sodium trial was a randomized trial conducted between September 1997 through November 1999, sponsored by the National Heart, Lung, and Blood Institute. The trial was initiated by investigators at 4 clinical centers within the United States (Baltimore, Maryland; Boston, Massachusetts; Durham, North Carolina; and Baton Rouge, Louisiana). Detailed methods have been published elsewhere (2). The DASH-Sodium trial was conducted as a follow-up to the DASH trial to determine the effects of sodium reduction on BP alone and in combination with the DASH diet. The DASH-Sodium trial compared the effects of consuming 3 different sodium levels in the context of either the DASH diet or a control diet, typical of what many Americans eat, that is, potassium, magnesium, and calcium intakes at the 25th percentile and average macronutrient profile of the U.S. population. Institutional review boards at each center approved the original study protocol, including subsequent analyses. Written, informed consent was provided by all participants.

PARTICIPANTS. The DASH-Sodium trial included adults, 22 years of age and older, with a SBP of 120 to 159 mm Hg and DBP of 80 to 95 mm Hg, based on the average BP across 3 screening visits. Persons with a prior diagnosis of heart disease, renal insufficiency, poorly controlled dyslipidemia, diabetes mellitus, or heart failure were excluded from participation (2). The trial also excluded persons taking antihypertensive agents or insulin, and persons drinking more than 14 alcoholic drinks a week.

DIETARY INTERVENTIONS. The trial tested 2 dietary factors, namely, dietary patterns and sodium levels. Participants were fed 1 of 2 dietary patterns (parallel design: DASH or control diet) and each of 3 sodium levels (crossover design: low, medium, or high). The DASH diet emphasized fruits, vegetables, and low-fat dairy foods with reduced intake of saturated fat, total fat, and cholesterol. The DASH diet included whole grains, poultry, fish, and nuts, and was reduced in red meat, sweets, and sugar-containing beverages. The control diet was typical of what many Americans eat (1).

Participants on either the DASH or control diets were fed each of 3 sodium levels: low, medium, and high (50 mmol or 1,150 mg, 100 mmol or 2,300 mg, and 150 mmol or 3,450 mg, respectively, at 2,100 kcal). The high level reflected average sodium intake in the United States. The medium level corresponded to prevailing sodium recommendations, whereas the lower level represented a level that might further lower BP. The levels of sodium intake were indexed to total energy requirements of each participant. A detailed composition of the diets may be found in Online Table 1 (4).

All meals and snacks were provided to participants. The participants' main meal (lunch or dinner) was consumed at the study centers under observation, whereas their remaining study meals were consumed offsite. Caloric intake was adjusted throughout the trial to keep participants' weight constant. All participants underwent a 2-week run-in period, during which they ate the high sodium-control diet. They were then randomized to either the DASH or control diet. On their assigned diet, participants consumed low, medium, or high sodium levels, each for 30 days. The order of sodium assignment was randomized, following a crossover design. Each of the sodium levels were separated by, on average, 5-day washout periods during which participants ate their usual diets. The intervention periods were completed by >98% of participants (2).

BP AND COVARIATE MEASUREMENTS. Consistent with the original DASH-Sodium trial, SBP was the primary outcome of this ancillary study. DBP was a secondary outcome. Both SBP and DBP were measured at the same time with random-zero sphygmomanometers while participants were seated. BP was measured at 3 visits during the screening phase and at 2 visits during the 2-week run-in period. The average of these 5 measurements served as a baseline for this study. BP was also measured at 5 clinic visits during the last 9 days of each intervention period (at least 2 during the final 4 days). Baseline SBP was organized in a priori strata <130, 130 to 139, 140 to 149, and ≥150 mm Hg on the basis of commonly used values to classify individuals. Baseline DBP was also organized in the following a priori strata: <80, 80 to 84, 85 to 89, and ≥90 mm Hg. Because eligibility for the trial was based on the 3 screening visits and because baseline was the average of BP at 3 screening visits and 2 run-in visits, some participants had a baseline BP below (or above) the eligibility cutpoints of the trial (i.e., <130 or ≥160 mm Hg systolic or <80 or >95 mm Hg diastolic).

Other population characteristics were determined via questionnaire, laboratory specimens, and physical examination. Body mass index (BMI) was derived from measured height and weight.

STATISTICAL ANALYSIS. We used mean ± SD and proportions to describe baseline population characteristics by diet assignment, overall, and across 4 strata of baseline SBP (<130, 130 to 139, 140 to 149, ≥150 mm Hg). Furthermore, the following contrasts were of interest: 1) low versus high sodium, separately in the control and DASH diets (sodium effect alone); 2) DASH versus control diets, separately at the high and low sodium levels (DASH effect alone); and 3) the low sodium-DASH diet versus the high sodium-control diet (combined effect).

For the first comparison (low vs. high sodium), we used the crossover design of the trial to compare SBP measured at the end of the low sodium period with SBP measured at the end of the high sodium period within the same participant. These analyses were performed via generalized estimating equation regression models with a Huber and White robust variance estimator (5), which conservatively assumed an exchangeable working correlation matrix. All analyses were adjusted for age, female sex, black race, and baseline BMI to address potential imbalances introduced by the stratified analysis.

The second and third comparisons involved the parallel design of the trial. For these analyses, we compared change in SBP from baseline to the end of either the high or low sodium period using linear regression. As with the first comparison, all analyses were adjusted for age, female sex, black race, and baseline BMI.

Differences between baseline SBP strata were determined using interaction terms in models restricted to the 2 baseline SBP strata being compared. The <130 mm Hg stratum served as a reference group. Trends across categories were determined using the median baseline SBP value within each of the baseline SBP strata and treating it as a continuous variable in an interaction term with the diet of interest.

In secondary analyses, we examined the effects of sodium reduction, DASH versus control, or both interventions on DBP in strata of baseline DBP values (<80, 80 to 84, 85 to 89, and ≥90 mm Hg). The <80 mm Hg stratum served as a reference group for comparisons across strata. Trends across categories were determined using the median baseline DBP value corresponding to each DBP stratum as above. All analyses were conducted with Stata version 14.0 (Stata Corporation, College Station, Texas). Missing data were minimal and evenly distributed throughout dietary interventions and time periods throughout the study.

RESULTS

BASELINE CHARACTERISTICS. Baseline characteristics of the 412 study participants are shown in Table 1. There were no significant differences between participants assigned the control or DASH diet overall. Among those assigned the control diet, age and proportion of women were higher in higher strata of baseline SBP. Among those assigned the DASH diet, age, proportion of women, and proportion black were higher in higher strata of baseline SBP. There were no clear trends in BMI across strata of baseline SBP in either arm.

LOW VERSUS HIGH SODIUM INTAKE. Among those assigned to the control arm, reducing sodium intake from high to low levels was associated with reductions in SBP of −3.20 (95% confidence interval [CI]: −4.96 to −1.44), −8.56 (95% CI: −10.70

TABLE 1 Baseline Characteristics Overall and by BP Strata According to Diet Assignment

		Baseline Systolic Blood Pressure, mm Hg			
	Overall	<130	130-139	140-149	≥150
Control	204	72	65	53	14
Age, yrs	49.1 ± 10.4	45.3 ± 8.7	48.3 ± 10.7	52.4 ± 9.9	59.0 ± 8.8
Women	111 (54.4)	32 (44.4)	37 (56.9)	32 (60.4)	10 (71.4)
Black	115 (56.4)	37 (51.4)	40 (61.5)	32 (60.4)	6 (42.9)
Blood pressure, mm Hg					
Systolic	135.4 ± 9.4	125.7 ± 3.2	134.7 ± 3.1	144.4 ± 3.0	154.5 ± 2.7
Diastolic	85.8 ± 4.1	84.0 ± 3.5	85.7 ± 3.8	87.2 ± 4.1	89.8 ± 4.2
Body mass index, kg/m^2	29.5 ± 5.0	29.7 ± 4.8	29.7 ± 5.4	29.7 ± 4.6	27.9 ± 6.0
Body mass index ≥30	82 (40.2)	25 (34.7)	28 (43.1)	24 (45.3)	5 (35.7)
DASH	208	76	69	51	12
Age, yrs	47.4 ± 9.6	43.6 ± 7.1	47.8 ± 9.2	49.5 ± 10.5	59.2 ± 8.6
Women	123 (59.1)	39 (51.3)	37 (53.6)	37 (72.5)	10 (83.3)
Black	119 (57.2)	41 (53.9)	40 (58.0)	30 (58.8)	8 (66.7)
Blood pressure, mm Hg					
Systolic	134.2 ± 9.6	124.6 ± 3.6	133.8 ± 2.9	144.1 ± 2.9	154.4 ± 3.5
Diastolic	85.6 ± 4.8	83.5 ± 4.0	86.3 ± 4.5	87.9 ± 4.9	85.3 ± 6.0
Body mass index, kg/m^2	28.8 ± 4.7	28.7 ± 4.1	29.6 ± 4.7	28.4 ± 5.1	27.4 ± 5.3
Body mass index ≥30	78 (37.5)	27 (35.5)	30 (43.5)	18 (35.3)	3 (25.0)

Values are n, mean ± SD, or n (%).

BP = blood pressure; DASH = Dietary Approaches to Stop Hypertension.

to −6.42), −8.99 (95% CI: −11.21 to −6.77), and −7.04 (95% CI: −12.92 to −1.15) mm Hg in strata of baseline SBP (<130, 130 to 139, 140 to 149, and ≥150 mm Hg, respectively) (**Table 2**). The trend across strata was statistically significant (p = 0.004).

Among those assigned to the DASH diet, reducing sodium intake from high to low levels was associated with reductions in SBP of −0.88 (95% CI: −2.07 to 0.30), −3.29 (95% CI: −4.71 to −1.88), −4.90 (95% CI: −7.25 to −2.55), and −10.41 (95% CI: −15.54 to −5.28) mm Hg in strata of baseline SBP (<130, 130 to 139, 140 to 149, and ≥150 mm Hg, respectively) (**Table 2**). This trend was also statistically significant (p < 0.001).

TABLE 2 Effect of Low Versus High Sodium on SBP in the Context of Control and DASH Diets

		Reducing Sodium (Low vs. High)			
Baseline SBP	N*	Mean Difference in SBP (95% CI)†	p Value Within Strata	p Value vs. <130 mm Hg Stratum	p for Trend‡
In control diet					
<130 mm Hg	70	−3.20 (−4.96 to −1.44)	<0.001	Ref	0.004
130-139 mm Hg	64	−8.56 (−10.70 to −6.42)	<0.001	<0.001	
140-149 mm Hg	53	−8.99 (−11.21 to −6.77)	<0.001	<0.001	
≥150 mm Hg	13	−7.04 (−12.92 to −1.15)	0.02	0.20	
In DASH diet					
<130 mm Hg	75	−0.88 (−2.07 to 0.30)	0.14	Ref	<0.001
130-139 mm Hg	68	−3.29 (−4.71 to −1.88)	<0.001	0.01	
140-149 mm Hg	49	−4.90 (−7.25 to −2.55)	<0.001	0.003	
≥150 mm Hg	12	−10.41 (−15.54 to −5.28)	<0.001	<0.001	

*Numbers do not entirely add to 204 for control or 208 for DASH due to missing measurements. †Adjusted for age, female sex, black race, and baseline body mass index. ‡Based on median value in each baseline systolic blood pressure category.

CI = confidence interval; DASH = Dietary Approaches to Stop Hypertension; Ref = reference value; SBP = systolic blood pressure.

DASH VERSUS CONTROL DIETS. During the high sodium feeding period, the DASH diet compared with the control diet significantly changed SBP by −4.47 (95% CI: −6.64 to −2.29), −4.26 (95% CI: −6.72 to −1.80), −4.72 (95% CI: −8.25 to −1.19), and −10.63 (95% CI: −18.86 to −2.41) mm Hg in strata of baseline SBP (<130, 130 to 139, 140 to 149, and ≥150 mm Hg, respectively) (**Table 3**). However, there was no significant trend across strata (p = 0.66).

Similarly, during the low sodium feeding period, the DASH diet compared with the control diet changed SBP by −2.36 (95% CI: −4.61 to −0.11), 0.92 (95% CI: −1.47 to 3.31), −0.55 (95% CI: −4.03 to 2.93), and −14.13 (95% CI: −25.61 to −2.64) in strata of baseline SBP (<130, 130 to 139, 140 to 149, and ≥150 mm Hg, respectively) without evidence of a trend across strata (p = 0.29).

LOW SODIUM-DASH DIET VERSUS HIGH SODIUM-CONTROL DIET. The mean SBP across strata of baseline SBP (<130, 130 to 139, 140 to 149, and ≥150 mm Hg) was 116, 124, 131, and 130 mm Hg on the low sodium-DASH diet versus 123, 133, 141, and 152 mm Hg on the high sodium-control diet, respectively (**Figure 1A**). Compared with the high sodium-control diet, the low sodium-DASH diet lowered SBP by −5.30 (95% CI: −7.66 to −2.94), −7.48 (95% CI: −10.11 to −4.84), −9.70 (95% CI: −13.34 to −6.06), and −20.79 (95% CI: −30.88 to −10.69) mm Hg across strata of baseline SBP (<130, 130 to 139, 140 to 149, and ≥150 mm Hg, respectively) (Online Table 2). Furthermore, there was evidence of a trend for greater reduction in SBP across strata of higher baseline SBP (p for trend <0.001).

SECONDARY OUTCOME: DBP. Analyses were repeated examining the effects of sodium reduction, the DASH diet (vs. control), and both dietary interventions on DBP across strata of baseline DBP (Online Tables 3 to 5). The pattern of DBP change by baseline DBP was virtually identical to that of SBP. **Figure 1B** displays DBP values on low sodium-DASH diet and high sodium-control diets.

DISCUSSION

In this trial, which enrolled adults with pre- or stage 1 hypertension, the combination of reduced sodium intake and the DASH diet lowered SBP throughout the range of SBP, with progressively greater reductions at higher levels of baseline SBP. Among persons with baseline SBP ≥150 mm Hg, mean SBP reduction was striking, (i.e., >20 mm Hg). In both the control and DASH diet, reducing sodium from high to low levels alone lowered SBP with progressively greater reductions at higher SBP. Meanwhile, the effects of the DASH diet differed by level of sodium. At the high sodium level, the DASH diet compared with the control diet lowered SBP in each stratum, but without a significant trend by baseline SBP; at the low sodium level, the effects of the DASH diet in the 4 strata of baseline SBP were inconsistent. These findings demonstrate that the individual and combined effects from both sodium reduction and the DASH diet are profound, particularly in hypertensive persons with higher BP.

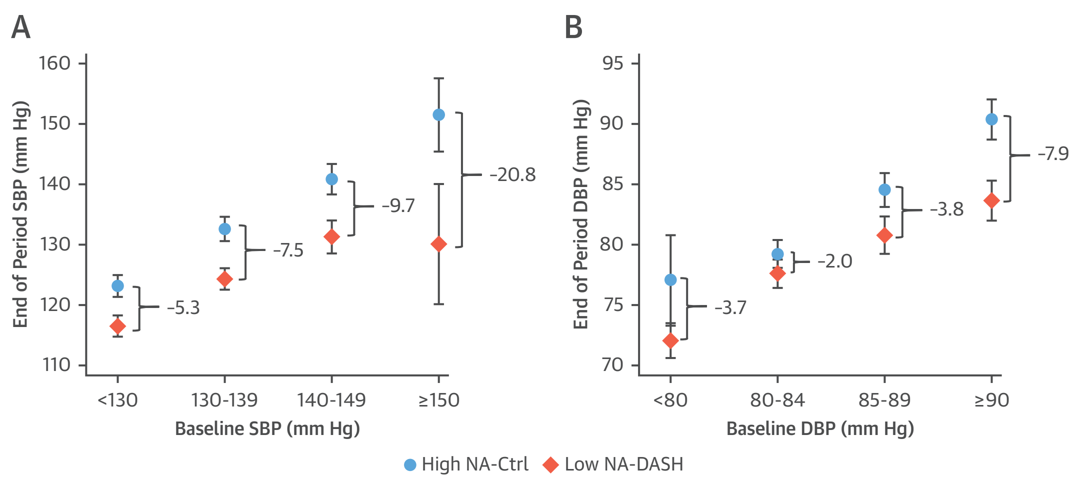
In children and adults, trials have shown that lowering dietary salt intake lowers BP (6,7). Trials often report effects overall or in nonhypertensive and hypertensive individuals. However, individual studies and meta-analyses provide scant information about the effects of sodium reduction by level of baseline BP and at high levels of BP. Analyses that stratify by hypertension status will differ from baseline BP analyses, underestimating the effect of sodium intake on BP. Among the few trials that have examined populations with more extreme baseline hypertension, one intervention trial of untreated adults with severe hypertension (mean SBP/DBP of 176/96 mm Hg), showed that sodium reduction (80 mmol/day compared with a typical diet) decreased SBP by 5 mm Hg (8). Similarly, a randomized feeding study by Pimenta et al. (9) in adults with uncontrolled hypertension despite using 3 or more antihypertensive agents (mean BP 146/84 mm Hg) demonstrated that sodium reduction (50 mmol/day compared with 250 mmol/day) decreased SBP by

TABLE 3 Effect of DASH Versus Control Diets on SBP According to Baseline SBP

Baseline SBP	N*	DASH vs. Control: Mean Difference in SBP (95% CI)†	DASH vs. Control: p Value Within Strata	DASH vs. Control: p Value vs. <130 mm Hg Stratum	p for Trend‡
At high sodium level					
<130 mm Hg	143	−4.47 (−6.64 to −2.29)	<0.001	Ref	0.66
130–139 mm Hg	130	−4.26 (−6.72 to −1.80)	0.001	0.78	
140–149 mm Hg	99	−4.72 (−8.25 to −1.19)	0.01	0.88	
≥150 mm Hg	25	−10.63 (−18.86 to −2.41)	0.02	0.04	
At low sodium level					
<130 mm Hg	141	−2.36 (−4.61 to −0.11)	0.04	Ref	0.29
130–139 mm Hg	129	0.92 (−1.47 to 3.31)	0.45	0.05	
140–149 mm Hg	100	−0.55 (−4.03 to 2.93)	0.76	0.31	
≥150 mm Hg	24	−14.13 (−25.61 to −2.64)	0.03	0.001	

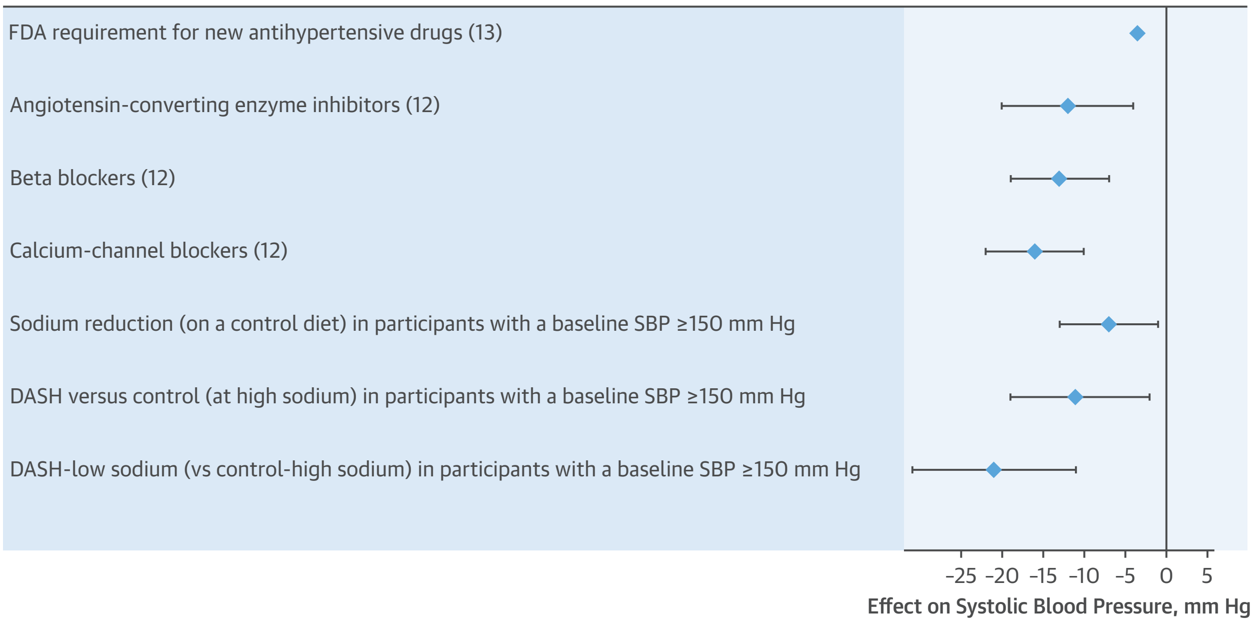
*Numbers do not entirely add to 412 due to missing measurements. †Adjusted for age, female sex, black race, and baseline body mass index. ‡Based on median value in each baseline systolic blood pressure category.
Abbreviations as in Table 2.

FIGURE 1 The Combined Effects of Low Sodium and the DASH Diet According to BP



Mean end of period systolic blood pressure measurements (mm Hg) by strata of **(A)** baseline systolic blood pressure (<130, 130 to 139, 140 to 149, ≥150 mm Hg) or **(B)** baseline diastolic blood pressure (<80, 80 to 84, 85 to 89, ≥90 mm Hg). Mean blood pressure values are presented by the high sodium-control diet **(circle)** or the low sodium-DASH diet **(diamond)**. Differences between diets were determined using linear regression comparing baseline changes in systolic or diastolic blood pressure adjusted for age, female sex, black race, and baseline body mass index. **Bars** indicate 95% confidence intervals. BP = blood pressure; Ctrl = control; DASH = Dietary Approaches to Stop Hypertension trial; DBP = diastolic blood pressure; NA = sodium; SBP = systolic blood pressure.

CENTRAL ILLUSTRATION **The BP Effects of the DASH Diet**



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Sodium reduction, alone or combined, compared with average BP effects of antihypertensive drug therapies and the FDA requirement for new antihypertensive drugs. Estimates for antihypertensive drug classes are taken from Manisty et al. (12). The FDA requirement for new antihypertensive drugs is taken from a committee meeting of the Center for Drug Evaluation and Research (2014) (13). BP = blood pressure; DASH = Dietary Approaches to Stopping Hypertension; FDA = Food and Drug Administration; SBP = systolic blood pressure.

22 mm Hg. Likewise, early analyses of the DASH trial and the DASH-Sodium trial did not stratify by hypertension severity. Thus, although the magnitude of BP lowering from either DASH or sodium reduction in those with baseline hypertension was greater than those without baseline hypertension, it was not as impressive as these other studies. By contrast, our current findings in the SBP ≥150 mm Hg group are virtually identical to the aforementioned studies.

The original DASH trial demonstrated that compared with control, DASH reduced SBP by 5.5 mm Hg overall and by 11.4 mm Hg among participants with hypertension at baseline (1,10,11). The sodium level of this trial was ~3 g per day (1). To place our results in context, compared to placebo, angiotensin-converting enzyme inhibitors reduce SBP by 12 mm Hg, beta blockers reduce SBP by 13 mm Hg, and calcium-channel blockers reduce SBP by 16 mm Hg **(Central Illustration)** (12). Similarly, the U.S. Food and Drug Administration recommends a minimum SBP-lowering effect of 3 to 4 mm Hg for new antihypertensive agents (13). Although we did not observe a higher magnitude of reduction among participants with a baseline SBP between 140 and 149, we did find a substantially greater reduction among those with a baseline SBP ≥150 mm Hg. The fact that the DASH diet with low sodium reduced BP compared with the control diet with high sodium reinforces the importance of modifying a dietary pattern when attempting to lower BP with diet. Although it has been hypothesized that potassium may be a particularly important nutrient in the DASH diet (14), unmeasured nutrients likely act synergistically via complex processes (15).

Our findings have both clinical and public health implications. In participants with hypertension, the DASH diet with low sodium, compared with the control diet with high sodium, lowered SBP by nearly 10 mm Hg among those with a baseline SBP of 140 to 149 mm Hg and >20 mm Hg among those with a baseline SBP ≥150 mm Hg. SBP levels between 140 and 159 mm Hg represent the majority of patients with hypertension (17). Thus, our findings suggest that most adults with uncontrolled BP can experience substantial reductions in SBP from dietary changes alone, reinforcing the importance of lifestyle interventions in the management of hypertension. The SBP reductions observed in those with pre-hypertension are lesser than those with hypertension, but still should lower the risk of subsequent cardiovascular disease (18,19).

This study has several strengths. It used a randomized design, included a diverse study population, and maintained high diet adherence and follow-up rates. Furthermore, BP was assessed by masked observers in triplicate with a standardized protocol, thereby increasing precision and minimizing bias. Finally, the impact of weight change was minimized by maintaining isocaloric feeding throughout the study.

STUDY LIMITATIONS. Adults with chronic kidney disease, medication-treated hypertension, medication-treated diabetes, and heart failure were excluded from participation, which could affect generalizability. The study also excluded adults with a SBP >160 mm Hg during screening visits. As a result, we cannot determine the effects of these interventions in persons with stage 2 hypertension. However, it is reasonable to speculate that BP reduction would be at least as great. Furthermore, there were fewer participants in the highest SBP stratum (i.e., >150 mm Hg) than other strata, which increases susceptibility to confounding, particularly with regard to parallel comparisons. Although we did not observe imbalances in baseline characteristics, and all our comparisons were adjusted for a number of baseline covariates, residual confounding is possible. Another limitation is study duration: the sodium intervention only lasted 4 weeks. Recent evidence suggests that BP effects from sodium reduction may not reach their full magnitude at 4 weeks (16). Finally, the study was not of sufficient size or duration to determine the effects of the interventions on cardiovascular events.

CONCLUSIONS

In conclusion, the combination of low sodium intake and the DASH diet was associated with substantially greater reductions in SBP among participants with a higher SBP at baseline compared with the combination of high sodium intake and the control diet. These findings reaffirm the importance of lifestyle interventions among adults with uncontrolled SBP. Further research is needed to determine the magnitude of SBP reduction that might be achieved in persons with SBP ≥160 mm Hg and in other conditions, including chronic kidney disease and congestive heart failure.

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PERSPECTIVES

COMPETENCY IN PATIENT CARE AND PROCEDURAL SKILLS: In adults with pre-hypertension, stage I hypertension, and baseline systolic blood pressure ≥150 mm Hg, the combination of the DASH diet and restriction of sodium intake can achieve substantial (>20 mm Hg) reductions in blood pressure.

TRANSLATIONAL OUTLOOK: Future studies should determine the magnitude of blood pressure reduction that can be achieved in patients with more severe hypertension and in those with heart failure and kidney disease.

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APPENDIX For supplemental tables, please see the online version of this article.