DASH Diet Score and Distribution of Blood Pressure in Middle-Aged Men and Women

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BACKGROUND
The Dietary Approaches to Stop Hypertension (DASH) Trial provides critical data on the impact of a specific diet pattern (low in salt, fat, and processed foods and high in fruit and vegetables) on blood pressure (BP). The effect of compliance with a DASH-type diet on BP in a general population sample is less well defined. We studied associations between a DASH style diet and BP.

METHODS
We used cross-sectional data from a study of men and women aged 47–73 years (n = 2,047). Participants completed a physical examination that included 3 standardized clinical BP recordings. A subsample (n = 1,187) had ambulatory BP measurements (ABPM) taken. Diet was assessed using a DASH dietary score constructed from a standard Food Frequency Questionnaire. Lower scores indicated less healthy diets. Hypertension was defined as clinic BP ≥ 140/90 mm Hg on medication or as 24-hour ABPM ≥ 130/80 mmHg.

RESULTS
Inverse associations were evident between DASH and systolic BP (SBP). There was a difference in clinic SBP of 7.5 mm Hg and 5.1 mm Hg and a difference in ABPM SBP of 6.3 mm Hg and 5.4 mm Hg in men and women, respectively, between the highest and lowest DASH quintiles. In fully adjusted multivariable regression analysis, DASH score was inversely associated with SBP. Clear population differences in SBP were evident across DASH quintiles.

CONCLUSIONS
The observed associations indicate that the findings are consistent with the hypothesis that adherence to DASH-equivalent diet can reduce BP at the population level. Public policy promoting a DASH-style healthy diet could have a significant impact on population health by reducing average BP in the population.

Keywords: blood pressure; DASH score; diet quality; hypertension.

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Hypertension poses a major public health challenge to health systems worldwide. Globally it is estimated that 26% of adults have hypertension.[1] It is the leading risk factor for mortality, the leading cause of disability-adjusted life years (7.0%; 95% uncertainty interval = 6.2%–7.7% of global disability-adjusted life years)[2] and is a leading risk factors for heart disease, stroke, and related cardiovascular disease in all populations. Capewell *et al.* estimated that if the hypertension prevalence in the United States was reduced to 16%, the target set in Healthy People 2010,[3] between 39,000 and 58,000 deaths from Coronary Heart Disease (CHD) could be prevented.[4] Despite this, awareness, treatment, and control of hypertension remain a problem worldwide.[5] Many countries have reported high proportions of their population with hypertension as unaware of their condition.[6] Given the increased risk in adverse health events across the spectrum of elevated blood pressure (BP) recordings, those with undiagnosed elevated BP pose a further public health challenge.

There is convincing evidence demonstrating the link between elevated BP and dietary habits. Specifically, the role of individual electrolytes and nutrients has long been established.[7–11] The INTERSALT study, a cross-sectional study that evaluated the relationship between BP and dietary electrolytes in >10,000 adults across 52 countries worldwide suggested a positive relationship between sodium intake and systolic BP (SBP); a difference of 100 mEq per day in sodium intake was associated with a difference of 3–6 mm Hg in SBP.[12] More recently, Graudal *et al.*[13] in their review on salt reduction on SBP indicated that sodium restriction resulted in an SBP decrease of −1.27 mm Hg to −4.02 mm Hg in normotensive adults and a decrease of −5.48 mm Hg to −10.21 mm Hg in hypertensive adults, equivalent to a 1% and a 3.5% decrease for normotensive and hypertensive adults, respectively. Other observational studies have reported inverse associations between BP and dietary potassium, calcium, and magnesium consumption.[12,14–17]

More recently, reducing BP based on whole diet intervention rather than specific nutrients has been shown to be successful in clinical trials.[18,19] The DASH (Dietary Approaches to Stop Hypertension) Trial was a multicenter, randomized feeding study that tested the combined effects of dietary patterns rather than single nutrients on BP.[19,20] The DASH dietary

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pattern, which was a combination diet based on high intakes of fruit and vegetables and low intakes of fat and sodium, showed beneficial reductions in SBP and diastolic BP (DBP) in both normotensive and hypertensive participants. Much of the evidence relating the DASH diet to BP stems from clinical trials and intervention studies[19,21–23] in the United States. However, in a small trial, Harnden *et al*. investigated the acceptability and applicability of the DASH diet in a free-living population in the United Kingdom.[24] They found that the DASH diet was easily adapted to the UK food preferences and habits. Among 14 trial participants, there was a significant reduction in SBP/DBP by 4.6/3.9 mm Hg after the trial.

In observational studies, diet quality indices based on the DASH diet[23] have been shown to be associated with reduced risk of coronary heart disease and stroke. This suggests that effects of the DASH trial interventions are potentially generalizable to the wider population and compliance with a DASH type diet will be associated with significant decrease in BP. However, data on associations between DASH and BP in the general population are lacking. This is the focus of our study. Specifically, we hypothesized that the population distribution of BP would be lower with higher compliance with a DASH-type diet. Given the imprecision with clinic BP readings, we also predicted that stronger associations with a DASH diet would be observed for ambulatory BP vs. clinic readings.

METHODS

This analysis uses data from the Mitchelstown Cohort Study, a cross-sectional study of middle-aged men and women conducted in Ireland in 2010–2011. Detailed methods of the study have been outlined elsewhere;[25] however, a brief summary is provided here.

Design

This was a cross-sectional study of 2,047 men and women aged 47–73 years (67% response rate), based in a primary care setting in the North Cork Region of the Republic of Ireland.[25] Participants were invited by letter to visit their general practitioner's (GP) practice office for a physical examination to be carried out by a nurse trained in the study research protocols. The clinical measurements included height, weight, BP, and pulse rate (3 readings). Additional measurements on a subset of participants in this study included 24-hour ambulatory BP measurement (ABPM) (n = 1,187).

Participants completed a detailed health and lifestyle survey questionnaire and a standard Food Frequency Questionnaire (FFQ), which was an adapted version of the EPIC study[26] validated for use in the Irish population.[27] All procedures were carried out with reference to the detailed guidelines outlined in the Standard Operating Procedures Manual, and all results were recorded on a standard Clinical Report Form.

Dietary habits

Participants completed a semiquantitative 156 item FFQ; details have been published elsewhere.[28] In summary, subjects were asked to indicate their average use of food items over the last year. Frequency of consumption of a medium serving or common household unit was asked for each food and later converted into quantities using standard portion sizes. The frequency categories were never or less than once a month, 1–3 times per month, once a week, 2–4 times per week, 5–6 times per week, once a day, 2–3 times per day, 4–5 times per day, and ≥6 times per day. Individual food items were combined into food groups with like-constituent foods grouped together.

Dietary quality assessment

Based on validated work,[23] we constructed a DASH score for each FFQ respondent. Details of the DASH score have been reported elsewhere;[29] however, in summary, it was a composite score derived from standard food groups within the FFQ as described by Fung and colleagues.[23] For each food group, consumption was divided into quintiles, and participants were classified according to their intake ranking. Consumption of healthy food components were rated on a scale of 1–5; the higher the score, the more frequent the consumption of that food (i.e., those in quintile 1 had the lowest consumption and received a score of 1; conversely, those in quintile 5 had the highest consumption and received a score of 5). Less-healthy dietary constituents, where low consumption is desired, were scored on a reverse scale, with lower consumption receiving higher scores. Component scores were summed, and an overall DASH score was calculated for each person, with a possible range of 9–45. Overall DASH score was subsequently collapsed to quintiles for analysis; lower quintiles indicated a poorer dietary quality. Quintile score ranges were as follows: quintile 1 (Q1): 13.00–21.37; Q2: 21.38–26.0; Q3: 25.99–28.96; Q4: 28.95–7.40; Q5: 37.41–45.00.

Blood pressure

Clinic BP was measured using an OMRON M7 (OMRON Healthcare, The Netherlands) in a seated position. Three readings were taken 1 minute apart. The mean of the second and third readings was used for analysis purposes. Ambulatory BP was measured using dabl ABPM system (dabl ltd., Ireland) with the Meditech ABOM-05 Monitor (Meditech Ltd., Hungary). The monitors remained in place for 24 hours, and BP was recorded every half hour.

Clinic hypertension was defined as SBP ≥ 140 mm Hg and/or DBP ≥ 90 mm Hg or on antihypertension medication. Overall ambulatory hypertension was defined as ≥130/80 mm Hg or on antihypertension medication.[30] Undiagnosed hypertension was defined as participants not on medication for hypertension and those who reported "no" to the question: "Have you ever been told by a doctor that you have 'hypertension?'"

Covariates

Body mass index. Each participant had their height and weight measured using standardized protocols and instruments. Body mass index was used as a continuous variable for this analysis.

Physical activity. Physical activity was assessed using the International Physical Activity Questionnaire (IPAQ).[31] For this analysis, the IPAQ was categorized using IPAQ short form protocol into low, moderate, or high categories.

Smoking. Participants were classified according to their current smoking status into 1 of 3 categories: never smoker, current smoker, or former smoker.

Alcohol. Participants were classified according to their current alcohol status into 1 of 3 categories: nondrinker (<1 unit per week); moderate (1–14 units per week); and heavy (>14 units per week).

Laboratory measurements. Participants provided an early morning spot urine sample. Laboratory analyses included analysis for sodium, potassium, creatinine, and urea.

Statistical analysis

Data were analyzed using Stata (version 12, StataCorp LP, Texas, USA). The association between risk factors and BP was assessed using univariable analysis and linear regression. Descriptive analyses were used to describe associations between hypertension and continuous variables, whereas cross tabulation with a χ^2 significance test was used to test associations with categorical variables. Significance for trends in univariable analysis was tested using the *nptrend* commands in Stata. In multivariable analysis, the DASH score (continuous) was entered as the independent variable. The fully adjusted models were adjusted for age, sex, education, BMI, smoking, physical activity, alcohol, and urinary sodium. Univariable results are presented for total population and undiagnosed population. Multivariable results are focused on the undiagnosed hypertensive population only. Distribution of SBP across DASH score quintiles was assessed using the kernel density estimates at the upper cutpoints of the DASH quintiles.

RESULTS

The sociodemographic characteristics of the Mitchelstown participants and the background population have been previously described;[25] however, a summary is provided in Table 1.

Hypertension prevalence

There was a 47% (95% confidence interval (CI) 44%–49%) prevalence of hypertension based on clinic readings (BP ≥ 140/90 mm Hg or on hypertensive medication) in this study population (49% men and 46% women). Almost one-quarter (23%; 95% CI = 21%–26%) of those with mean BP readings above the cutpoint of 140/90 mm Hg were unaware of their elevated BP status (undiagnosed hypertension). The prevalence of hypertension, based on ambulatory BP readings (BP ≥ 130/80 mm Hg or on hypertensive medication) was 20% (25% men; 16% women).

Univariable analysis of DASH score and SBP

Clear inverse associations were seen between dietary quality and SBP. Table 2 shows the distribution of clinic BP for the total population and for those with undiagnosed hypertension. Results are presented for all participants and stratified by sex. Table 3 presents the same data for ambulatory BP.

Table 1. Demographic characteristics of participants and background population at baseline, Mitchelstown cohort

	Participants			Background population[a]		
Characteristic	Men, no. (%)	Women, no. (%)	Total, no. (%)	Men, no. (%)	Women, no. (%)	Total, no. (%)
Age, years[b]						
50–54	191 (22.8)	203 (22.8)	394 (22.8)	11,025 (31.9)	10,521 (31.6)	21,546 (31.7)
55–59	227 (27.1)	228 (25.6)	455 (26.3)	9,925 (28.7)	9,532 (28.6)	19,457 (28.6)
60–64	208 (24.8)	242 (27.2)	450 (26.0)	7,783 (22.5)	7,567 (22.7)	15,350 (22.6)
65–69	213 (25.4)	216 (24.3)	429 (24.8)	5,852 (16.9)	5,686 (17.0)	11,538 (17.0)
Marital status						
Single	122 (12.4)	55 (5.3)	177 (8.8)	5,331 (15.4)	2,918 (8.8)	8,249 (12.1)
Cohabiting/married	778 (78.9)	808 (78.5)	1,586 (78.7)	25,553 (73.9)	24,217 (72.7)	49,770 (73.3)
Separated/divorced	62 (6.3)	71 (6.9)	133 (6.6)	2,542 (7.3)	2,654 (8.0)	5,196 (7.6)
Widowed	24 (2.4)	95 (9.2)	119 (5.9)	1,159 (3.3)	3,517 (10.5)	4,676 (6.9)
Education[c]						
Primary	310 (32.7)	227 (23.6)	537 (28.1)	19,346 (16.4)	16,512 (41.3)	35,858 (15.4)
Secondary	455 (48.0)	481 (50.1)	936 (49.1)	65,223 (55.3)	57,712 (50.0)	122,935 (52.7)
Tertiary	183 (19.3)	252 (26.3)	435 (22.8)	33,307 (28.2)	41,060 (35.6)	74,367 (31.9)

[a]Age calculated on date of study participation.
[b]Census 2006 SAPS (small area population statistics) Themes by Electoral Division, County and Province, Cork County.
[c]Background population aged ≥15 years and highest level of education completed, Cork County.

Table 2. Unadjusted distribution of clinic blood pressure by DASH score in middle-aged men and women

	All participants with BP measurements[a]						Participants with undiagnosed hypertension[b]					
DASH quintile[c]	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	P_{trend}[d]	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	P_{trend}[d]
Total participants	n = 1,488						n = 1,260					
Mean SBP (SD)	131.3 (16.4)	129.0 (17.6)	128.5 (16.4)	129.6 (17.0)	126.8 (16.6)	0.005	129.4 (16.5)	127.1 (16.5)	125.7 (15.0)	126.4 (14.9)	122.1 (15.4)	<0.001
Mean DBP (SD)	80.9 (9.9)	79.8 (9.8)	80.0 (9.3)	80.0 (10.3)	79.8 (9.6)	0.25	79.9 (9.7)	78.8 (9.9)	79.2 (8.7)	79.2 (9.8)	78.2 (9.5)	0.14
Hypertensive[e], % (no.)	33.6 (118)	29.6 (82)	27.5 (74)	29.9 (98)	27.3 (72)	0.12	28.4 (67)	27.7 (46)	19.6 (35)	22.2 (46)	18.9 (32)	0.01
Men	n = 724						n = 589					
Mean SBP (SD)	132.6 (15.7)	130.5 (15.0)	129.6 (15.3)	130.9 (16.2)	128.6 (15.4)	0.05	131.0 (15.1)	130.1 (14.7)	127.8 (14.6)	128.6 (14.4)	123.6 (14.1)	0.005
Mean DBP (SD)	80.7 (10.1)	79.7 (9.1)	79.3 (8.5)	79.8 (10.4)	78.9 (9.4)	0.14	79.7 (9.8)	79.5 (9.5)	78.8 (7.7)	79.7 (10.2)	77.2 (8.9)	0.17
Hypertensive[e], % (no.)	34.1 (75)	31.1 (46)	28.1 (36)	29.7 (44)	23.8 (19)	0.09	28.7 (41)	31.8 (28)	19.8 (18)	24.4 (21)	13.6 (6)	0.03
Women	n = 764						n = 671					
Mean SBP (SD)	129.3 (17.4)	127.3 (20.0)	127.5 (17.3)	128.5 (17.6)	126.1 (17.0)	0.33	127.1 (18.4)	123.9 (17.9)	123.5 (15.2)	124.8 (15.1)	121.6 (15.8)	0.08
Mean DBP (SD)	81.3 (9.4)	79.8 (10.6)	80.7 (10.1)	80.2 (10.2)	80.1 (9.7)	0.58	80.2 (9.5)	78.1 (10.2)	79.5 (9.6)	78.8 (9.5)	78.6 (9.8)	0.48
Hypertensive[e], % (no.)	32.8 (43)	27.9 (36)	26.9 (38)	30.2 (54)	28.8 (53)	0.66	28.1 (26)	23.1 (18)	19.3 (17)	20.7 (25)	20.8 (26)	0.21

Abbreviations: BP, blood pressure; DASH, Dietary Approaches to Stop Hypertension; DBP, diastolic blood pressure; SBP, systolic blood pressure.
[a]Hypertension defined as BP ≥ 140/90 mm Hg.
[b]Undiagnosed answered “no” to the question, “Have you ever been told you had hypertension?” or not on treatment, medications, or diet for hypertension.
[c]Quintile 5 = highest quality diet; Quintile 1 = poorest quality diet.
[d]Trend based on nonparametric trend using DASH as a continuous variable.
[e]Hypertension defined on BP ≥ 140/90mmHg or on antihypertensive medication.

Table 3. Unadjusted distribution of overall ambulatory blood pressure by DASH score in middle-aged men and women

	All Participants with BP measurements[a]						Participants with undiagnosed hypertension[b]					
DASH quintile[c]	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	P_{trend}[d]	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	P_{trend}[d]
Total Participants			n = 876						n = 516			
Mean SBP (SD)	125.8 (14.1)	124.6 (11.9)	124.0 (12.3)	123.8 (13.5)	119.3 (11.9)	<0.001	124.5 (15.3)	122.7 (12.2)	122.4 (11.3)	120.9 (12.1)	115.6 (11.6)	<0.001
Mean DBP (SD)	73.6 (8.8)	71.4 (8.3)	71.6 (8.1)	71.8 (8.5)	69.2 (7.5)	<0.001	73.4 (9.0)	71.9 (9.2)	71.9 (7.6)	71.2 (8.5)	68.4 (7.4)	<0.001
Hypertensive[e], % (no.)	18.8 (40)	9.1 (14)	9.0 (14)	11.5 (22)	6.2 (10)	0.001	17.4 (24)	11.8 (10)	9.4 (8)	6.2 (7)	5.2 (5)	0.001
Men			n = 408						n = 243			
Mean SBP (SD)	127.9 (13.3)	126.7 (10.5)	126.1 (12.2)	126.6 (12.4)	123.0 (11.2)	0.05	127.5 (14.6)	125.9 (10.8)	125.9 (11.7)	125.2 (11.6)	121.1 (11.9)	0.06
Mean DBP (SD)	75.8 (8.8)	73.6 (7.9)	74.7 (8.6)	74.8 (8.5)	72.0 (6.9)	0.04	75.6 (9.0)	74.2 (8.9)	74.7 (7.5)	74.4 (9.1)	72.3 (7.2)	0.11
Hypertensive[e], % (no.)	22.3 (29)	11.0 (9)	17.7 (12)	18.3 (15)	10.9 (5)	0.22	22.0 (18)	13.5 (7)	16.7 (7)	13.0 (6)	14.3 (3)	0.23
Women			n = 468						n = 273			
Mean SBP (SD)	122.3 (14.6)	122.1 (13.1)	122.4 (12.3)	121.7 (13.9)	117.8 (12.0)	0.02	120.0 (15.3)	117.8 (12.7)	119.0 (9.9)	117.8 (11.5)	114.1 (11.1)	0.03
Mean DBP (SD)	70.8 (8.0)	69.0 (7.9)	69.2 (6.9)	69.6 (7.8)	68.1 (7.5)	0.04	70.2 (8.1)	68.4 (8.8)	69.3 (6.7)	68.9 (7.3)	67.3 (7.1)	0.07
Hypertensive[e], % (no.)	13.3 (11)	6.9 (5)	2.3 (2)	6.4 (7)	4.3 (5)	0.03	10.7 (6)	9.1 (3)	2.3 (1)	1.5 (1)	2.7 (2)	0.01

Abbreviations: BP, blood pressure; DASH, Dietary Approaches to Stop Hypertension; DBP, diastolic blood pressure; SBP, systolic blood pressure.
[a] Hypertension defined as BP ≥ 140/90 mm Hg.
[b] Undiagnosed answered "no" to the question, "Have you ever been told you had hypertension" or not on treatment, medications, or diet for hypertension.
[c] Quintile 5 = highest quality diet; Quintile 1 = poorest quality diet.
[d] Trend based on nonparametric trend using DASH as a continuous variable.
[e] Hypertension defined as BP > 130/80mmHg or on antihypertensive medication.

Total population (treated, untreated, and undiagnosed). In unadjusted analyses based on the total sample population with BP readings, trends were evident for clinic BP (Table 2) and ABPM (Table 3). Significant associations were evident for participants with poor dietary quality and SBP. There was a difference in SBP of 4.4 mm Hg and 6.4 mm Hg for participants with the poorest diet (lowest DASH score) compared with the best diet (highest DASH) in clinic BP and ABPM, respectively. Similar differences were seen when stratified by sex (Men: 4.0 mm Hg and 4.9 mm Hg, respectively, for clinic BP and ABPM; Women: 3.2 mm Hg and 4.5 mm Hg for clinic BP and ABPM, respectively).

Undiagnosed population. Clear inverse associations were seen with dietary quality and SBP in clinic readings. Higher DASH scores (highest quality diet) were associated with lower SBP in men and women. Between the lowest DASH quintile and the highest quintile clinic SBP differed by 7.3 mm Hg, 7.4 mm Hg, and 5.5 mm Hg for all undiagnosed subjects, undiagnosed men, and undiagnosed women, respectively. Overall ambulatory SBP differed by 8.9 mm Hg, 6.4 mm Hg, and 5.9 mm Hg for all undiagnosed subjects, undiagnosed men, and undiagnosed women, respectively (Table 2).

Inverse associations were seen across DASH quintile for hypertension in clinic BP (Table 2) and ABPM (Table 3). For men, rates of hypertension changed by 15% and 8% in clinic BP and ABPM, respectively, between the healthiest diet group and the worst diet group. For women, these differences were 7% and 8%, respectively.

Multivariate analysis of DASH score and BP

A sequential multiple linear regression analysis was employed to enhance our understanding of how lifestyle behaviors impact (confound) the DASH and SBP relationship in the undiagnosed population (Tables 4 and 5). DASH Score and SBP were entered into the model as continuous variables for this analysis.

Clinic BP. DASH score remained inversely associated with SBP. In the undiagnosed population (Table 4), DASH score was significantly negatively correlated with clinic SBP. A 5-unit increase in DASH score was associated with a 1.9 mm Hg increase in SBP (β = −1.93; 95% CI = −2.80 to −1.05; P < 0.001). In further adjustments, with the addition of each confounding variable sequentially, DASH remained significantly inversely associated with SBP (β = −1.29; 95% CI = −2.48 to −0.11; P = 0.03). Adjusting for urinary sodium borderline attenuated the association between DASH and SBP (β= −1.10; 95% CI = −2.29 to 0.09; P = 0.07).

ABPM. Similar patterns were seen in the ABPM readings; however, DASH score was more strongly associated with SBP in ABPM than in clinic readings (Table 5). DASH score was significantly inversely associated with overall ambulatory SBP. In unadjusted analysis, a 5-unit increase in DASH score was associated with a 2.68 mm Hg increase in SBP (β = −2.68, 95% CI =−3.63 to −1.72; P < 0.001) and with a 2 mm Hg increase in fully adjusted analyses (β = −2.00; 95% CI = −3.24 to −0.76; P = 0.002). Adjusting for urinary sodium did not alter the association between DASH and SBP (β = −1.99; 95% CI = −3.23 to −0.75; P = 0.002).

Clinic SBP distribution across DASH score quintiles

Figure 1 and Figure 2 show the kernel density estimates for the fully adjusted SBP distributions across DASH score quintiles for the total undiagnosed population in clinic and ambulatory readings, respectively. Clear positive distribution differences in SBP can be seen across DASH quintiles in both clinic and ambulatory readings. Similar but more pronounced differences are seen across DASH quintiles for ABPM SBP (Figure 2).

SBP and other dietary components

The associations between the individual food groups that comprise the DASH score (DASH components) and SBP were examined (Table 6). Although overall DASH score remains inversely significantly associated in unadjusted, partially adjusted, and fully adjusted models, individual components, with the exception of low fat milk, have no independent relationship with clinic SBP.

Table 4. Adjusted distribution of clinic systolic blood pressure for a 5-unit increase in DASH score in Irish men and women (undiagnosed population)

	DASH score coefficient	SE	95% CI		*P* value
Unadjusted	−1.93	0.44	−2.80	−1.06	<0.001
+Sex, age, education	−1.48	0.47	−2.40	−0.57	0.002
+Body mass index	−1.44	0.45	−2.33	−0.55	0.001
+Smoking status	−1.28	0.46	−2.18	−0.37	0.006
+Physical activity	−1.37	0.48	−2.31	−0.42	0.005
+Alcohol	−1.29	0.60	−2.48	−0.11	0.03
+Urinary sodium	−1.10	0.61	−2.29	0.09	0.07

Abbreviation: DASH, Dietary Approaches to Stop Hypertension.

Table 5. Adjusted distribution of ambulatory systolic blood pressure for a 5-unit increase in DASH score in Irish men and women (undiagnosed population)

	DASH score coefficient	SE	95% CI		*P* value
Unadjusted	−2.86	0.49	−3.63	−1.72	<0.001
+Sex, age, education	−1.82	0.50	−2.80	−0.83	<0.001
+Body mass index	−1.79	0.47	−2.72	−0.86	<0.001
+Smoking status	−1.73	0.48	−2.68	−0.78	<0.001
+Physical activity	−1.67	0.49	−2.64	−0.70	0.001
+Alcohol	−2.00	0.63	−3.24	−0.76	0.002
+Urinary sodium	−1.99	0.63	−3.23	−0.75	0.002

Abbreviation: DASH, Dietary Approaches to Stop Hypertension.

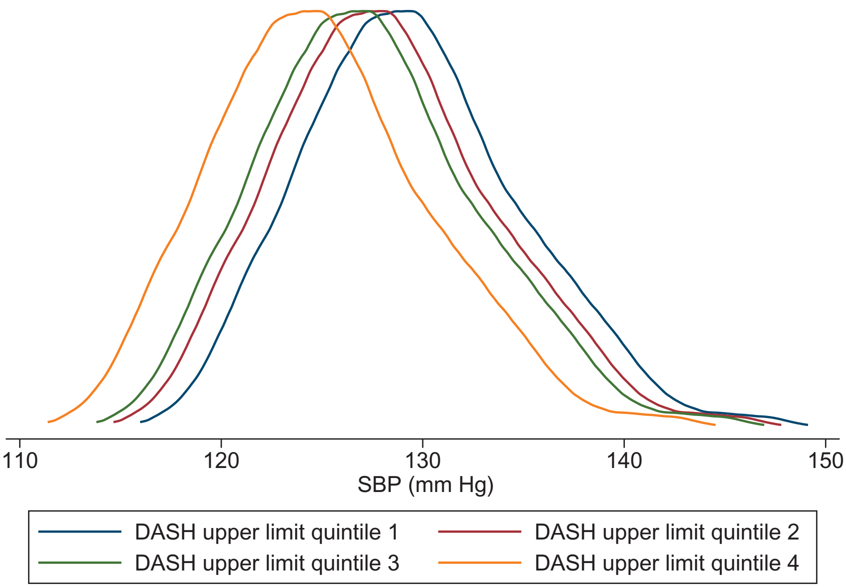

Figure 1. Kernel density distribution of clinic systolic blood pressure (SBP) by Dietary Approaches to Stop Hypertension (DASH) score in men and women (undiagnosed population).

DISCUSSION

First, independent of age, education, body mass index, smoking, and physical activity, DASH score was significantly inversely associated with SBP in standardized clinic recordings and with ABPM. Adjustment for lifestyle behaviors did not alter the significant association between dietary quality and SBP. Second, we demonstrated the stronger association between dietary intake and elevated BP using ambulatory BP readings compared with standardized clinic BP readings. Third, clear population differences in SBP are evident across DASH score quintiles; this is consistent with current models of the determinants of distribution of BP in the population. Associations between DASH and ambulatory BP were stronger than with clinic BP.

Our findings support the evidence of the beneficial effects of a high-quality diet on BP in the general population. In fact, our estimates are potentially underestimated because the FFQ does not measure the relevant dietary exposures with precision. In particular, it does not capture discretionary salt intake. The results of this cross-sectional study further support the population generalizability of the results of clinical trials, such as the DASH trial, which are conducted in controlled settings with highly motivated individuals.[19,20] In a free-living population–based study, Khaw *et al.*[32] reported a significant increase in SBP (approximately 7 mm Hg) between lowest sodium quintiles and highest sodium quintiles. Our findings demonstrate a similar dose–response effect between high DASH quintiles (high-quality diet) and SBP in both clinic BP and ABPM recordings, particularly for men. The public health implications of these differences are contextualized by the work of the Prospective Studies Collaboration,[33,34] where it was found that at ages 40–69 years, each difference of 20 mm Hg usual SBP was associated with >2-fold difference in the stroke death rate and with 2-fold differences in the death rates from IHD and from other vascular causes. Among men and women aged 60–69 years, a 10 mm Hg lower SBP was associated with

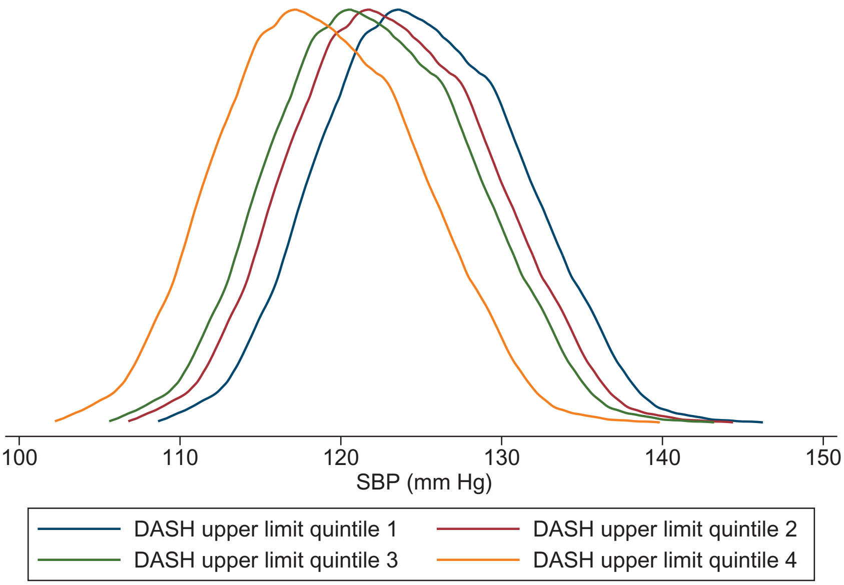

Figure 2. Kernel density distribution of ambulatory systolic blood pressure (SBP) by Dietary Approaches to Stop Hypertension (DASH) score in men and women (undiagnosed population).

Table 6. Adjusted distribution of clinic systolic blood pressure by individual food groups in older Irish men and women (undiagnosed population)

	Model 1			Model 2			Model 3		
	Coefficent	SE	95% CI	Coefficient	SE	95% CI	Coefficient	SE	95% CI
Whole grains	−0.4	0.3	−1.1 to 0.12	−0.1	0.4	−1.0 to 0.8	−0.2	0.5	−1.1 to 0.7
Vegetables	0.4	0.3	−0.3 to 1.0	0.8	0.4	−0.03 to 1.6	0.8	0.4	−0.01 to 1.7
Fruit	−0.2	0.3	−0.9 to 0.5	−0.2	0.5	−1.1 to 0.7	−0.2	0.5	−1.1 to 0.7
Legumes	−0.1	0.3	−0.8 to 0.5	−0.4	0.4	−1.2 to 0.4	−0.4	0.4	−1.3 to 0.4
Low-fat milk	−0.9	0.3	−1.5 to −0.3	−0.8	0.4	−1.6 to −0.1	−0.8	0.4	−1.6 to −0.1
Low-fat dairy	−0.6	0.3	−1.2 to −0.1	−0.5	0.3	−1.1 to 0.2	−0.5	0.3	−1.1 to 0.2
Sweet snacks	0.4	0.3	−0.3 to 1.1	−0.1	0.5	−1.0 to 0.8	−0.1	0.5	−1.0 to 0.9
Sodium	−0.2	0.3	−0.8 to 0.5	−0.1	0.4	−0.9 to 0.8	−0.2	0.6	−1.4 to 1.1
Red meat	0.3	0.3	−0.3 to 0.9	0.6	0.4	−0.2 to 1.4	0.6	0.4	−0.2 to 1.4
Salty snacks	0.6	0.3	−0.02 to 1.2	0.5	0.5	−0.3 to 1.3	0.5	0.4	−0.3 to 1.4
Overall DASH Score	−0.3	0.1	−0.5 to −0.1	−0.2	0.1	−0.5 to −0.003	−0.3	0.1	−0.5 to −0.02

Model 1: Adjusted for sex, age, education. Model 2: Adjusted for sex, age, education, body mass index, alcohol, smoking, physical activity. Model 3: Adjusted for sex, age, education, body mass index, alcohol, smoking, physical activity, and kilocalorie intake.
Abbreviation: DASH, Dietary Approaches to Stop Hypertension.

about one-fifth lower risk of a CHD event. We hypothesized that the associations in our sample would be stronger for ambulatory BP than clinic BP, given that it is a more precise measure of BP. Our results support this hypothesis, thus further supporting the measurement of BP over a 24-hour period.

It could be argued that the diet–BP associations evident in these analyses is driven by the low salt component of the diet pattern; however, in this analysis it can be seen that the sum of the parts exerts a greater effect than the individual components. After adjustment for urinary sodium in the undiagnosed population, diet quality remained inversely associated with SBP. This indicates that for this population subgroup, it is important to assess the whole diet when exploring the diet–disease associations.

Limitations of the study include the cross-sectional design of the survey, the relatively modest response rate (67%), and the issue of measurement error in relation to the exposure (diet quality) and the health outcomes (BP and hypertension). By definition, we have to be cautious in making causal links in cross-sectional analyses. However, the findings presented here are entirely consistent with available experimental data, in particular the DASH trials.[18–20] There is also a possibility of some recall bias in fruit and vegetable and salt intake, especially from people with known hypertension. However, this would not apply in this analysis because we excluded previously diagnosed hypertension. It should also be noted that misclassification of exposures and outcomes due to random error tends to underestimate the effect sizes, and it is highly likely that the magnitude of the associations seen between diet and hypertension in our study have been underestimated. Measurement of BP in a clinic setting, even with multiple readings, is associated with measurement error. Our study is strengthened by the use of 24-hour ambulatory BP recording, which increases precision of the BP readings; however, the ambulatory BP monitors were not randomly distributed, thus selection bias cannot be ruled out.

Our findings suggest that at a population level, differences in SBP are evident between groups with high-quality and poor-quality diets. Our findings are consistent with the hypothesis that within the spectrum of the typical Western diet modest dietary differences that result in a positive dietary quality change are positively associated with SBP.[35] Given the direct relationship between increasing BP and adverse health events and that a substantial proportion of events can be attributed to even moderately elevated BP, a broader population-based approach to diet modification rather than an approach targeted at high-risk individuals is warranted.[36] The high level of undiagnosed hypertension in our population further supports the recommendation of a wide population-based approach. Although we cannot ascertain cause and effect from this study, our results support the hypothesis that public policy promoting a DASH-style healthy diet could have a significant impact on population health by reducing average BP in the population.

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DISCLOSURE

The authors declared no conflict of interest.

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