British Journal of Nutrition (2012), **108**, 1678–1685
doi:10.1017/S000711451100715X

Dietary Approaches to Stop Hypertension (DASH) eating pattern and risk of elevated blood pressure in adolescent girls

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(Submitted 16 March 2011 – Final revision received 3 October 2011 – Accepted 28 November 2011 – First published online 16 January 2012)

Abstract

Dietary determinants of adolescent blood pressure (BP) are poorly understood. The goal of the present study was to assess the effects of an eating pattern similar to that from the Dietary Approaches to Stop Hypertension (DASH) study on adolescent BP. Data from 2185 girls followed-up over 10 years (until the girls were 18–20 years of age) in the National Heart Lung and Blood Institute's Growth and Health Study were used in this analysis. Diet was assessed during eight examination cycles using 3 d dietary records; girls were classified according to their consumption of foods associated with a DASH-style eating pattern. Analysis of covariance modelling, multiple logistic regression and longitudinal mixed models were used to control for potential confounding by age, race, socio-economic status, height, physical activity, television viewing time and other dietary factors. Girls who consumed ≥2 daily servings of dairy and ≥3 servings of fruits and vegetables (FV) had a 36 % lower risk (95 % CI: 0·43, 0·97) of elevated BP (EBP) in late adolescence. In longitudinal modelling, two dietary factors were associated with a lower systolic BP throughout adolescence: higher (≥2 daily servings) dairy intakes ($P<0·0001$) and a DASH-style pattern ($P=0·0002$). Only the DASH-style pattern led to consistently lower diastolic BP levels ($P=0·0484$). Adjustment for BMI did not appreciably modify the results. In this study, adolescent girls whose diets were rich in dairy products and FV during the early- and mid-adolescent years were less likely to have EBP levels in later adolescence.

Key words: Diet: Blood pressure: Adolescence

The original 1997 Dietary Approaches to Stop Hypertension (DASH) clinical trial randomly assigned adults with a diastolic blood pressure (DBP) between 80 and 95 mmHg and a systolic blood pressure (SBP) <160 mmHg to one of three dietary patterns: a control diet, a high-fruit and vegetable diet, or a diet high in fruits and vegetables (FV) as well as low-fat dairy products (the 'combined' diet)[1]. The 'combined' dietary pattern (generally termed the DASH diet) was characterised by the highest intakes of Ca and Mg; fibre and K intakes were similar in the fruit-and-vegetable and combined diets. The combined DASH eating pattern led to the greatest blood pressure (BP)-lowering effects regardless of initial BP level when compared with either the control diet or the high-fruit-and-vegetable diet. Subsequent studies confirmed these results[2].

The PREMIER trial demonstrated only modest BP benefits from adding a DASH-style dietary intervention to other lifestyle measures[3] while the Exercise and Nutrition Interventions for Cardiovascular Health (ENCORE) Study, which examined DASH in combination with an exercise or weight reduction intervention in overweight and obese adults, found that the beneficial effects of DASH were even stronger among those who exercised or lost weight[4]. Other studies[5], such as the French Supplementation en Vitamines et Mineraux Antioxydants (SU.VI.MAX) study, found beneficial effects from FV intake but not from dairy.

BP levels track from childhood to adulthood[6] and recent data from the Fels Longitudinal Study indicate that childhood SBP is a strong predictor of the risk of both hypertension

Abbreviations: BP, blood pressure; DASH, Dietary Approaches to Stop Hypertension; DBP, diastolic blood pressure; EBP, elevated blood pressure; FV, fruits and vegetables; NGHS, National Heart Lung and Blood Institute's Growth and Health Study; SBP, systolic blood pressure; SES, socio-economic status; USDA, United States Department of Agriculture.

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https://doi.org/10.1017/S000711451100715X Published online by Cambridge University Press

and the metabolic syndrome later in life[7]. A limited number of studies have examined the effects of a DASH-style eating pattern among children and adolescents. In the Framingham Children's Study, those whose early diets were characterised by higher intakes of both dairy products and FV had lower SBP by early adolescence[8]. Results from a small clinical trial of pre-hypertensive/hypertensive adolescents showed that a DASH-like dietary intervention was more effective than routine care in lowering SBP[9]. Finally, in a cross-sectional study, children and adolescents with type 1 diabetes mellitus whose diets most resembled a DASH pattern were least likely to be hypertensive[10].

The goal of the present analyses is to evaluate the effects of the DASH eating pattern and its components on adolescent BP.

Methods

The present analyses were approved by the Boston University Institutional Review Board and use data from the National Heart Lung and Blood Institute's Growth and Health Study (NGHS). The NGHS enrolled 2379 Black and White girls, aged 9–10 years at baseline, from three urban and suburban clinical sites. The girls were followed-up annually for 10 years. Details of the study design and methods have been previously published[11,12]. Diet was assessed using 3 d dietary records collected on two weekdays and one weekend day during study years 1–5, 7, 8 and 10. After completion, a study dietitian carried out a standard debriefing with each subject following the certification guidelines of the University of Minnesota's Nutrition Coordinating Center. Finally, the dietitian classified each record as reliable or not based on standard rules; unreliable record days were excluded from the analyses. Nutrient intakes were calculated using the Nutrition Data System of the Nutrition Coordinating Center[13].

Data on the child's food intake as defined by Food Pyramid servings were derived from the diet records by the investigators at Boston University; Nutrition Data System food codes were linked with those from the United States Department of Agriculture (USDA)'s 'Pyramid Serving Database for USDA Survey Food Codes, version 2'[14]. Exact matches between the two databases were found for about 70 % of codes; for the remaining codes, a food with similar nutrient content was identified and the estimated Pyramid servings were then adjusted to parallel the differences in nutrient content. The final Food Pyramid data set contains each subject's intake in the five major food groups (i.e. fruit, vegetables, dairy, meat/other proteins, grains) and all subgroups.

BP was measured annually using a standardised protocol. A total of three measurements were taken with a standard mercury sphygmomanometer (Baum Desktop Model, V-Lok Cuffs). Elevated BP (EBP) was defined as being at or above the 90th percentile for age, sex and height based on the National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents[15].

Potential confounders

Socio-economic status (SES) was classified as low, moderate or high based on education and household income. High SES reflected an income of $40 000 or more and a parent with more than a high-school education, while low SES included all families with an income of <$10 000 (regardless of education) and those earning up to $20 000 who had a high-school education or less. All others fell into the moderate SES category. Race was self-determined as Black or White; approximately equal numbers of each racial group were enrolled.

Physical activity was assessed during years 1, 3, 5 and 7–10 with the Health Activity Questionnaire, an instrument that was validated in adolescent girls for measuring participation in structured games, sports and classes[16]. The Health Activity Questionnaire score was computed after multiplying an estimate of the metabolic equivalents for each activity by the frequency of participation. At each annual visit, the usual number of hours spent watching television and videos each day was assessed by questionnaire. Height and weight were measured in standardised fashion and BMI was estimated as (weight (kg)/height (m)^2). BMI was evaluated as a potential explanatory variable in the final models.

Statistical analysis

Usual servings per day in the five major USDA food groups were estimated as average servings from all days of diet records collected between the ages of 9 and 17 years. The analyses focused on the principal components of the combined DASH eating pattern: FV and dairy products. On average, girls in the study consumed less than the recommended intakes in these food groups, and so it was necessary to define low, moderate or high intakes using data-derived cutpoints. The following outcomes were explored: mean SBP and DBP at the end of follow-up in late adolescence and adjusted mean BP throughout the follow-up period (at 2-year intervals). All analyses were performed using Statistical Analysis Systems software, version 9.1 (SAS Institute).

We used ANCOVA models to derive adjusted mean SBP and DBP at the end of follow-up (ages 18–20 years). Final models contained the following potential confounding variables: age, race, SES, height, mean physical activity level, and hours of television/video per day. In secondary analyses, mean BMI at 18–20 years of age was added to the final models to evaluate its role as a potential explanatory variable.

Multiple logistic regression analysis was used to estimate the relative risk of having EBP in late adolescence (18–20 years) associated with intake in the DASH-related food groups: fruit, vegetables, combined FV, dairy, whole grains, lean meats (including lean red meat, poultry and fish), and nuts, seeds and legumes. To assess the effects of the primary components of the DASH eating pattern, both FV and dairy intakes were dichotomised (<3 *v.* ≥ 3 servings/d for FV; <2 *v.* ≥ 2 servings for dairy) and then combined into one of four mutually exclusive categories: (a) low intakes of both dairy and FV, (b) low intake of dairy and high intake of FV, (c) high intake of dairy but low intake of FV, and (d) high intakes of both dairy and FV. Cutpoints were chosen in part to optimise analytic power.

Finally, longitudinal mixed models were used to estimate the adjusted mean SBP and DBP levels at six points throughout adolescence associated with the aforementioned four categories of intake. Age, SES, race, height, physical activity score, television/video watching and daily intakes of whole grains, lean meats (including red meats, poultry and fish), and nuts, seeds and legumes were included in these models.

Results

Table 1 shows selected descriptive data for NGHS girls according to their combined intakes of dairy products and FV. Those with lower intakes of dairy products as well as lower intakes of FV consumed the least energy ($P<0.0001$) but had the highest BMI at baseline ($P<0.0001$). Girls with a DASH-style eating pattern (with higher intakes of dairy products and FV) were somewhat more active and watched less television than girls in the other categories of intake, $P<0.0001$). The DASH eating pattern was also associated with slightly lower energy-adjusted intakes of total fat as well as energy from solid fat and added sugars compared with the other eating patterns. Similarly, those girls with a DASH-like eating pattern consumed more fibre and had higher mean intakes of Ca, Mg and K than those following other eating patterns.

Table 2 shows the adjusted mean SBP and DBP levels associated with intakes in various DASH-related food groups. There were no striking trends towards lower BP associated with higher intakes in most food groups. However, higher intakes of nuts, seeds and legumes were associated with a significantly lower DBP levels in late adolescence ($P=0.003$).

For the baseline model in Table 3, we retained only those potential confounding variables that were strong independent predictors of EBP or that led to a change of 5 % or more in the adjusted relative risk estimates. In these analyses, consuming ≥4 servings of FV led to a (non-statistically significant) 32 % reduction in risk of EBP. Consuming two or more servings of dairy products led to a 33 % reduction in risk of EBP. In separate analyses (not shown), we found that consuming ≥2 servings of low-fat dairy products (*v.* less) led to a 42 % reduction in EBP risk (relative risk: 0·58; 95 % CI: 0·39, 0·86). There was little if any association between other DASH-related food groups and EBP. Model 2 in Table 3 adds BMI at 18–20 years of age to explore whether body fat might explain some of the observed dietary effects on BP. We do not include BMI in the main models since we hypothesise that BMI is a part of the causal pathway. The modest attenuation of the relative risk estimates in Model 2 suggests that some of the effects of FV or dairy product intakes may be explained by intermediate effects on BMI.

In Table 4, we classified girls according to their combined intakes of FV and dairy products to determine whether the effect of combined intakes differed from the independent effects of these two food groups. Girls with low intakes of both FV and dairy products served as the referent category. While there was no effect of high FV intake alone, high dairy product intake led to about a 25 % (non-statistically significant) reduction in the risk of EBP. High intakes of both dairy products and FV (a DASH-style pattern) led to a 36 % reduction in risk (95 % CI: 0·43, 0·97). These effects were only slightly attenuated by the inclusion of BMI in the multivariable models.

Finally, we used longitudinal mixed modelling to examine the effects of a DASH-style eating pattern on SBP (Fig. 1(a)

Table 1. Descriptive characteristics of girls according to patterns of dairy product and fruit and vegetable (FV) intake
(Mean values and standard deviations)

	Combined intakes of dairy products and FV								
	Dairy <2·0, FV <3·0 svgs (*n* 731)		Dairy <2·0, FV ≥3·0 svgs (*n* 919)		Dairy ≥2·0, FV <3·0 svgs (*n* 273)		Dairy ≥2·0, FV ≥3·0 svgs (*n* 405)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P* for trend
Baseline characteristics									
Age (years)	10·0	0·6	10·0	0·6	10·0	0·6	10·0	0·6	0·4180
Height (cm)	141·1	7·8	141·7	7·8	140·5	7·4	141·2	7·5	0·7717
Weight (kg)	38·5	10·9	37·7	10·2	36·1	9·7	36·0	9·3	<0·0001
BMI (kg/m^2)	19·1	4·1	18·6	3·8	18·1	3·6	17·9	3·4	<0·0001
Activity score (METS)*	18·2	9·4	19·9	9·8	20·9	10·3	23·6	12·3	<0·0001
TV/video (h)*	5·0	1·9	4·9	2·1	4·1	1·9	3·8	2·2	<0·0001
Mean macronutrient intakes*									
Energy (kJ/d)	6961	1276	8119	1489	7789	1374	8839	1457	<0·0001
Energy from protein (%)	14·1	2·0	13·7	1·8	14·7	1·9	14·7	1·7	<0·0001
Energy from carbohydrates (%)	50·8	4·9	52·1	4·9	51·0	4·7	52·3	4·7	<0·0001
Energy from fat (%)	35·9	3·7	35·2	4·0	35·3	3·7	34·2	4·1	<0·0001
Energy from saturated fat (%)	13·1	1·6	12·5	1·5	13·8	1·7	13·0	1·8	0·0428
Energy from solid fat and added sugar (%)	42·8	4·8	41·0	5·1	41·8	5·2	39·2	5·1	<0·0001
Mean micronutrient intakes*									
Ca (mg)	634	134·7	672	137·7	1004	163·4	1076	169·9	<0·0001
Mg (mg)	176	33·5	212	39·3	222	36·5	263	41·5	<0·0001
K (mg)	1604	267·0	2070	352·0	2041	295·8	2553	386·1	<0·0001
Na (mg)	2786	582·4	3220	713·5	2977	594·5	3434	691·4	<0·0001

svgs, Servings/d; METS, metabolic equivalents; TV, television.
* Mean values from ages 9–17 years.

British Journal of Nutrition

https://doi.org/10.1017/S000711451100715X Published online by Cambridge University Press

Table 2. Dietary intake and mean blood pressure (BP) levels in late adolescence

(Mean values with their standard errors)

Mean servings/d (ages 9–17 years)	*n*	BP (ages 18–20 years) SBP* Mean	SE	DBP* Mean	SE
Total fruit					
< 1·0	995	109·0	0·3	65·6	0·3
1·0–<2·0	831	109·4	0·3	65·7	0·3
≥ 2·0	359	108·3	0·4	64·6	0·4
P for trend		0·480		0·091	
Total vegetables					
< 1·5	513	109·4	0·4	65·8	0·3
1·5–<3·0	1390	108·9	0·2	65·4	0·2
≥ 3·0	282	109·3	0·5	65·4	0·5
P for trend		0·603		0·409	
Fruit and vegetables					
0–<2·0	242	109·3	0·5	66·4	0·5
2·0–<4·0	1372	109·0	0·2	65·4	0·2
≥ 4·0	571	108·9	0·3	65·3	0·3
P for trend		0·458		0·177	
Total dairy					
<1·0	345	109·2	0·4	65·9	0·4
1·0–<2	1210	109·2	0·2	65·4	0·2
≥ 2	630	108·5	0·3	65·5	0·3
P for trend		0·161		0·579	
Whole grains					
<0·25	499	108·7	0·4	65·3	0·4
0·25–<0·50	1445	109·3	0·3	66·0	0·3
≥ 0·50	241	109·0	0·3	65·2	0·3
P for trend		0·543		0·695	
Lean meat, poultry, fish					
<1·0	360	108·8	0·4	65·6	0·4
1·0–<3·0	1520	109·0	0·2	65·6	0·2
≥ 3·0	305	109·3	0·5	65·0	0·5
P for trend		0·436		0·353	
Nuts, seeds, legumes					
0<0·25	1222	109·0	0·2	65·8	0·2
0·25–<0·50	667	109·4	0·3	65·6	0·3
≥ 0·50	296	108·3	0·5	64·0	0·5
P for trend		0·384		0·003	

SBP, systolic BP; DBP, diastolic BP.

* Adjusted for age, race, socio-economic status, height, activity score, television/video watching.

and (b)) and DBP (Fig. 2(a) and (b)) over 10 years of follow-up. In this study, two eating patterns were associated with lower SBP levels throughout most of adolescence – higher intakes of dairy products alone ($P<0·0001$) as well as the DASH pattern (with higher intakes of both dairy products and FV ($P=0·0002$). For DBP, the DASH eating pattern was associated with the lowest BP ($P=0·0484$) throughout follow-up. Figs. 1(b) and 2(b) for both SBP and DBP show the effect of adding BMI at each age to the multivariable models. It is evident from these analyses that an independent effect of diet remains after controlling for BMI.

Discussion

In the present study, girls who consumed two or more servings of dairy products/d were much less likely to have EBP by the end of follow-up in late adolescence. Total FV intake had a similar overall effect, but vegetables alone had a weaker effect on BP outcomes. The combined intakes of ≥2 servings of dairy products and ≥3 servings of FV/d throughout adolescence led to about a 35% lower risk of EBP by late adolescence. These results suggest that the beneficial effects of FV combined with dairy products that were identified in the initial DASH trials may also apply to free-living adolescent girls. While some attenuation of the beneficial effects associated with the combined dietary pattern in this study occurred when BMI was added to the models, an independent effect remained. Finally, although intakes of nuts, seeds and legumes were low among NGHS girls, those who consumed at least 0·5 servings/d had lower BP at the end of follow-up.

Several adult studies have examined the DASH pattern with higher intakes of fruit, vegetables and dairy products. Data from the EPIC-Potsdam Study showed that the DASH eating pattern led to a lower long-term risk of hypertension compared with two other patterns (‘traditional cooking’ and a high-fruit-and-vegetable diet)[17]. In contrast, a different study found that only the FV components of the DASH pattern were associated with lower BP[5]. A beneficial effect of total FV intake on BP has been shown in a number of epidemiological studies and clinical trials in different population groups[18,19].

Few studies have examined the effects of a DASH eating pattern on BP in younger subjects. A small 3-month randomised trial of adolescents with EBP found that a DASH diet was more effective in lowering SBP compared with a ‘routine diet’[9]. Data from young children in the Framingham Children’s Study showed that the combined intakes of dairy products and FV were associated with significantly smaller yearly increases in BP over 8 years (from pre-school to early adolescence)[8]. In the Coronary Artery Risk Development in Young Adults (CARDIA) study, higher intakes of plant-based foods (whole and refined grains, fruit, vegetables, nuts and legumes) in young adults were inversely associated with 15-year incidence of EBP.

There are a number of possible mechanisms by which a diet rich in fruits, vegetables and dairy products may benefit BP. First, these foods are important sources of Ca, Mg and K, all of which have been associated with lower BP through regulation of vascular resistance and promotion of vasodilation. A low K:Na ratio is associated with increases in renal Na retention (through decreases in the synthesis of NO), thereby raising BP[20,21]. Correcting low K intakes may also reduce salt sensitivity and lower BP by reducing peripheral vascular resistance. Mg may contribute to lowering BP by acting as a natural Ca-channel blocking agent[21]. It is also involved in the regulation of intracellular Ca, K and Na and alters insulin sensitivity and vascular resistance.

FV consumption may benefit BP by raising antioxidant capacity and lowering oxidative stress[22]. These foods also provide high levels of phytochemicals including flavonols, phytosterols and polyphenols[23]; and while the mechanisms by which these compounds may have an impact on BP are not yet known, there is growing evidence of beneficial effects[24].

While some studies have found vegetable protein to be inversely associated with BP[25], we found no independent beneficial effect of vegetable consumption in this study. Glutamic acid is the amino acid in vegetable protein most closely

https://doi.org/10.1017/S000711451100715X Published online by Cambridge University Press

Table 3. Risk of elevated blood pressure (EBP) in late adolescence according to dietary intake
(Relative risks (RR) and 95 % confidence intervals)

		RR of EBP at end of follow-up (18–20 years)				
			Baseline model*		Model 2†	
Servings/d (ages 9–17 years)	*n*	EBP cases‡	RR	95 % CI	RR	95 % CI
Total fruit						
< 1	995	144	1·00	–	1·00	–
1–<2	831	135	1·17	0·91, 1·52	1·22	0·93, 1·59
≥ 2·0	359	33	0·66	0·44, 1·00	0·68	0·44, 1·04
Total vegetables						
< 1·5	513	75	1·00	–	1·00	–
1·5–<3	1390	196	0·93	0·69, 1·24	1·03	0·76, 1·39
≥ 3·0	282	41	0·88	0·58, 1·34	1·01	0·66, 1·56
Fruit and vegetables						
0–<2	242	45	1·00	–	1·00	–
2–<4	1372	191	0·73	0·51, 1·05	0·81	0·56, 1·18
≥ 4·0	571	76	0·68	0·45, 1·02	0·76	0·49, 1·16
Total dairy products						
< 1·0	345	57	1·00	–	1·00	–
1·0–<2	1210	190	1·00	0·72, 1·39	1·06	0·75, 1·48
≥ 2	630	65	0·67	0·45, 0·99	0·72	0·48, 1·08
Whole grains						
< 0·25	499	72	1·00	–	1·00	–
0·25–<0·50	698	111	1·15	0·83, 1·59	1·26	0·90, 1·77
≥ 0·50	988	129	0·99	0·72, 1·36	1·07	0·77, 1·48
Lean meat, poultry, fish						
< 1·0	360	52	1·00	–	1·00	–
1·0–<3·0	1520	204	0·85	0·61, 1·18	0·79	0·56, 1·12
≥ 3·0	305	56	1·11	0·73, 1·69	1·07	0·69, 1·65
Nuts, seeds, legumes						
0–0·25	1222	176	1·00	–	1·00	–
0·25–<0·50	667	100	1·10	0·84, 1·44	1·15	0·87, 1·52
≥ 0·50	296	36	0·81	0·55, 1·19	0·87	0·59, 1·30

* Adjusted for height, activity score and television/video watching in baseline model.
† Model 2 includes all baseline variables + BMI.
‡ EBP defined as ≥90th percentile for age, sex and height (National High Blood Pressure Education Program Working Group).

linked with BP, but NGHS girls consumed very little soya or other legumes. In addition, they had generally low intakes of K-rich vegetables such as lima beans, beets, brussel sprouts, spinach or winter squash. Thus, the absence of a beneficial effect of vegetables in this study may be related to the types of vegetables consumed.

The independent role of dairy products in BP control is controversial. In a recent review of dietary therapy for hypertension, Sacks & Campos[26–28] concluded that dairy products and their related nutrients failed to lower BP in controlled trials of subjects with hypertension. However, the DASH trial is at odds with these findings. In addition, a number of prospective epidemiological studies have found dairy product consumption (especially low-fat dairy products) to be inversely associated with BP levels[29–32]. In a recent review, Kris-Etherton *et al.*[33] concluded that the

Table 4. Effect of Dietary Approaches to Stop Hypertension (DASH)-style eating pattern on risk of elevated blood pressure (EBP) in late adolescence
(Relative risks (RR) and 95 % confidence intervals)

		RR of EBP at end of follow-up (18–20 years)				
			Baseline model*		Model 2†	
Servings/d (ages 9–17 years)	*n*	EBP cases‡	RR	95 % CI	RR	95 % CI
DASH-style pattern§						
Low dairy products/low FV	686	105	1·00	–	1·00	–
Low dairy products/high FV	869	142	1·06	0·80, 1·40	1·14	0·85, 1·52
High dairy products/low FV	252	28	0·75	0·48, 1·18	0·81	0·51, 1·29
High dairy products/high FV	378	37	0·64	0·43, 0·97	0·69	0·45, 1·05

FV, fruit and vegetables.
* Adjusted for height, activity score and hours of watching television and videos.
† Model 2 includes all baseline variables + BMI.
‡ EBP defined as ≥90th percentile for age, sex and height (National High Blood Pressure Education Program Working Group).
§ High *v.* low dairy = ≥2 *v.* <2 servings/d. High *v.* low FV intake = ≥3 *v.* <3 servings/d.

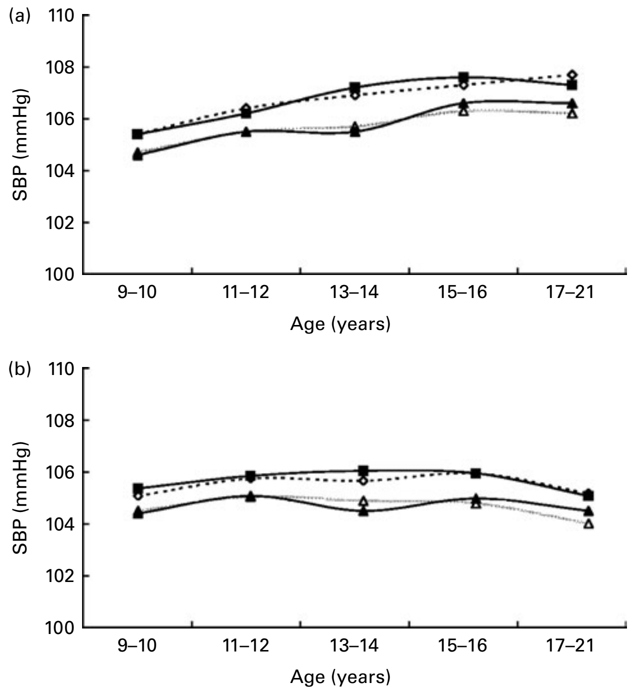

Fig. 1. (a) Effect of Dietary Approaches to Stop Hypertension (DASH) eating pattern on systolic blood pressure (SBP). Overall group differences are as follows: low dairy products/high fruits and vegetables (FV) *v.* low/low ($P=0·9392$), high dairy products/low FV *v.* low/low ($P<0·0001$), high dairy products/high FV *v.* low/low ($P=0·0002$). Eating patterns are as follows: low *v.* high dairy products: <2 *v.* ≥ 2 servings/d and low *v.* high FV: <3 *v.* ≥ 3 servings/d. SBP was adjusted for age, race, socio-economic status (SES), height, activity score, television/video watching, intake of whole grains, lean meats, seeds and legumes. (b) Effect of DASH pattern on SBP after controlling for BMI. Overall group differences are as follows: low dairy products/high FV *v.* low/low ($P=0·1769$), high dairy products/low FV *v.* low/low ($P=0·0013$), high dairy products/high FV *v.* low/low ($P=0·0022$). Eating patterns are as follows: low *v.* high dairy products: <2 *v.* ≥ 2 servings/d and low *v.* high FV: <3 *v.* ≥ 3 servings/d. SBP was adjusted for age, race, SES, height, activity score, television/video watching, intake of whole grains, lean meats, seeds and legumes and BMI at each age. -◇-, low dairy products and low FV, -■-, low dairy products and high FV, ··△··, high dairy products and low FV and -▲-, high dairy products and high FV.

epidemiological evidence supports the intake of three servings of dairy products/d (particularly low-fat dairy) for the lowering of BP. A meta-analysis of nine randomised, controlled trials found hypotensive effects of dairy product-derived tripeptides[34]. The renin–angiotensin system is a crucial regulator of BP via angiotensin-I-converting enzyme pathways. Angiotensin-I-converting enzyme inhibitory peptides found in both milk and cheese have been shown to inhibit the renin–angiotensin system, leading to a decrease in BP[33].

There are a number of possible mechanisms by which a diet rich in nuts, seeds and legumes may benefit BP. Nuts are high in MUFA and PUFA. Those with higher amounts of n-3 fatty acids in particular, have been linked with lower BP[35]. Nuts, seeds and legumes contain high amounts of other plant-derived amino acids, such as arginine and glutamic acid, which have also been linked with BP-lowering effects. These amino acids are believed to inhibit the renin–angiotensin system, enhance insulin sensitivity, reduce oxidative stress and improve endothelial function[36].

The present study has numerous strengths including its prospective design with 10 years of follow-up throughout adolescence, the extensive number of 3 d dietary records, and the replicate measures of BP and potential confounders. In addition, the complete ascertainment of food group intakes that were derived by the authors by linking Nutrition Data System data with USDA Food Pyramid data is an added strength.

Despite using a gold-standard method for dietary assessment, younger subjects in particular have difficulty in reporting portion sizes and the details of foods eaten. This type of measurement error associated with diet (or other behavioural factors) would most probably be non-differential. While under-reporting of diet may be a concern, it has been shown that the reporting of intake at meals is much more complete than is the reporting of snack foods, even among overweight/obese individuals[37]. Thus, under-reporting is not likely to be an important problem in this study. To further reduce the possibility of bias, we included only dietary records that were collected before the measurement of BP at 18–20 years of age. One additional limitation in this study is that

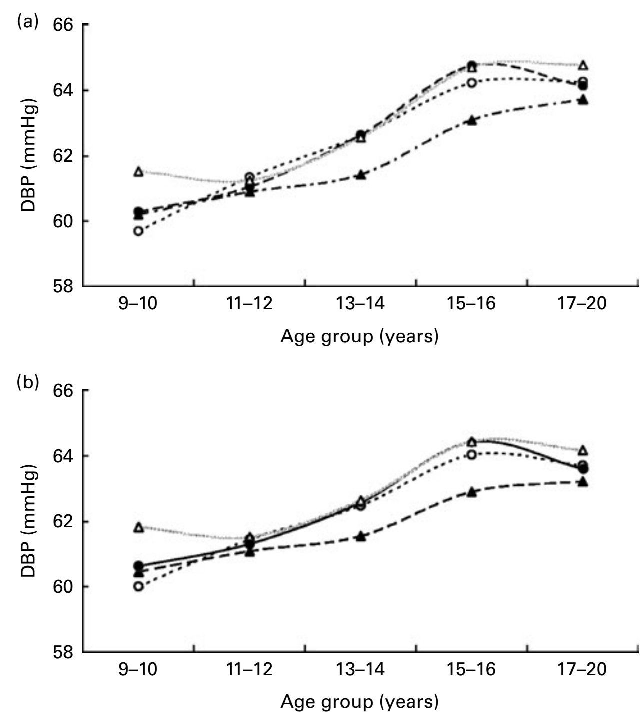

Fig. 2. (a) Effect of Dietary Approaches to Stop Hypertension (DASH) eating pattern on diastolic blood pressure (DBP). Overall group differences are as follows: low dairy products/high fruits and vegetables (FV) *v.* low/low ($P=0·5043$), high dairy products/low FV *v.* low/low ($P=0·0704$), high dairy products/high FV *v.* low/low ($P=0·0484$). Eating patterns are as follows: low *v.* high dairy products: <2 *v.* ≥ 2 servings/d and low *v.* high FV: <3 *v.* ≥ 3 servings/d. DBP was adjusted for age, race, socio-economic status (SES), height, activity score, television/video watching, intake of whole grains, lean meats, seeds and legumes. (b) Effect of DASH pattern on DBP after controlling for BMI. Overall group differences are as follows: low dairy products/high FV *v.* low/low ($P=0·2507$), high dairy products/low FV *v.* low/low ($P=0·1810$), high dairy products/high FV *v.* low/low ($P=0·0084$). Eating patterns are as follows: low *v.* high dairy products: <2 *v.* ≥ 2 servings/d and low *v.* high FV: <3 *v.* ≥ 3 servings/d. DBP was adjusted for age, race, SES, height, activity score, television/video watching, intake of whole grains, lean meats, seeds and legumes and BMI at each age. ··○··, low dairy products and low FV, -●-, low dairy products and high FV, ··△··, high dairy products and low FV and -▲-, high dairy products and high FV.

the limited range of intake for some food groups such as whole grains or legumes made it difficult to assess the effects of these foods.

In clinical trials, a DASH eating pattern in adults has been shown to have important BP-lowering effects. This study adds to a growing body of evidence that this dietary pattern may have beneficial effects on changes in BP earlier in life. In this study, a diet rich in dairy products and FV during the early- and mid-adolescent years led to a lower risk of EBP in later adolescence.

Acknowledgements

This paper was prepared using 'National Heart Lung and Blood Institute Growth and Health Study' research data obtained from the National Heart Lung and Blood Institute. The analyses described were supported by grant no. R21DK075068 from the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) and a grant from the National Dairy Council. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIDDK or the National Institutes of Health. All authors reviewed and approved the final version of this paper. L. L. M. wrote the manuscript and assumes overall responsibility for the conception, design and interpretation of the underlying analyses. M. L. B. contributed to the understanding of the literature and the interpretation of these results, particularly in the context of the existing knowledge, as well as participating in the editing of the manuscript. M. R. S. was largely responsible for the methodology associated with linking Nutrition Data System food codes with the USDA Food Pyramid servings. She conducted analyses in the later stages of the project and contributed to the interpretation of nutritional analyses. M. M. Q. was responsible for data management and analysis throughout much of the project and contributed to the interpretation of results. J. R. B. participated in editing and interpreting the manuscript. S. R. D. was the Principal Investigator of the NGHS and was integrally involved in all components of the original study. He reviewed and edited the present manuscript. None of the authors has any conflict of interest to disclose.

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