



HAL
open science

Dietary patterns and blood pressure change over 5-y follow-up in the SU.VI.MAX cohort

Luc Dauchet, Emmanuelle Kesse-Guyot, Sébastien Czernichow, Sandrine Bertrais, Carla Estaquio, Sandrine Péneau, Anne-Claire Vergnaud, Stacie Chat-Yung, Katia Castetbon, Valérie Deschamps, et al.

► **To cite this version:**

Luc Dauchet, Emmanuelle Kesse-Guyot, Sébastien Czernichow, Sandrine Bertrais, Carla Estaquio, et al.. Dietary patterns and blood pressure change over 5-y follow-up in the SU.VI.MAX cohort. *The American Journal of Clinical Nutrition*, 2007, 85 (6), pp.1650-1656. <10.1093/ajcn/85.6.1650>. <hal-04824117>

HAL Id: hal-04824117

<https://hal.science/hal-04824117v1>

Submitted on 15 May 2025

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons CC BY 4.0 - Attribution - International License

Dietary patterns and blood pressure change over 5-y follow-up in the SU.VI.MAX cohort¹⁻³

Luc Dauchet, Emmanuelle Kesse-Guyot, Sébastien Czernichow, Sandrine Bertrais, Carla Estaquio, Sandrine Péneau, Anne-Claire Vergnaud, Stacie Chat-Yung, Katia Castetbon, Valérie Deschamps, Pauline Brindel, and Serge Hercberg

ABSTRACT

Background: Although short-term effects of the Dietary Approaches to Stop Hypertension (DASH) diet on blood pressure have been shown in intervention studies, less is known about the long-term effects.

Objective: The aim was to study the relation between dietary patterns based on DASH diet characteristics and blood pressure (BP) and BP change in a clinical trial of antioxidants conducted in France from 1994 to 2002.

Design: Repeated 24-h dietary records were collected during the first year of follow-up. Dietary variables studied included fruit and vegetables, dairy products and fat (defined by Keys score), and two hypothesis-oriented scores based on the DASH diet. We performed a cross-sectional analysis of BP measured at the first clinical examination (1995–1996) in 4652 participants aged 35–63 y and a longitudinal analysis of BP change over a median follow-up of 5.4 y ($n = 2341$).

Results: The mean increases in systolic (SBP) and diastolic (DBP) BPs were 9.3 and 4.5 mm Hg, respectively. After adjustment for potential confounders, higher fruit and vegetable consumption was associated with lower SBP and DBP at first clinical examination (P for trend < 0.02 for both) and a lower 5-y increase in SBP (-2.1 mm Hg in the 4th compared with the 1st quartile; P for trend < 0.004) and DBP (-0.7 mm Hg in the 4th compared with the 1st quartile; P for trend < 0.03). The 2 DASH scores also were significantly associated with a lower BP at the first clinical examination and a lower BP increase. No significant relations were observed with dairy products or Keys score in either analyses.

Conclusion: These results suggest that high fruit and vegetable intakes may be associated with a lower increase in BP with aging. *Am J Clin Nutr* 2007;85:1650–6.

KEY WORDS Dietary pattern, blood pressure, cohort, epidemiology, cardiovascular disease

INTRODUCTION

Hypertension is a highly prevalent cardiovascular disease risk factor due to the common rise in blood pressure with advancing age (1, 2). A better understanding of factors that account for blood pressure increase with age could contribute to improved prevention of hypertension.

The critical role of diet in the prevention of hypertension has been established in intervention trials (3–6). One key study is the Dietary Approaches to Stop Hypertension (DASH) trial (3). This

study showed that a diet emphasizing increased fruit, vegetable, and low fat dairy consumption, in addition to decreased total fat and low saturated fat intakes, substantially lowered blood pressure (BP) during an 8-wk intervention. This finding has been strengthened by results from the Nurses' Health Study and the Health Professionals Follow-up Study groups, which found a lower risk of coronary heart disease and stroke associated with a prudent dietary pattern characterized by higher intakes of fruit, vegetables, legumes, fish, and whole grains (7, 8). There is an accumulating amount of evidence on the BP-lowering effect of this diet over short-term periods (3–6), and recent diet recommendations are based on the results of the DASH trial (9). However, less is known about the effect of this diet over several years and its effect on age-related BP increase. The objective of our study was to investigate the relations between both BP and 5-y BP changes and dietary patterns based on the DASH eating plan in free living middle-aged French men and women participating in the SU.VI.MAX cohort.

SUBJECTS AND METHODS

Population

The design, methods, and rationale of the SU.VI.MAX study have been reported elsewhere (10, 11). Briefly, the French SU.VI.MAX study was initially designed as a randomized, double blind, placebo-controlled, primary prevention trial to test the efficacy of a daily supplementation with antioxidant vitamins and minerals at nutritional doses in reducing the incidence of ischemic heart diseases and cancer. In total, 13 017 participants were included from 1994 to 1995 with a planned follow-up of 8 y.

¹ From UMR U557 INSERM; U1125 INRA; CNAM; Paris 13 University, Centre de Recherche en Nutrition Humaine-IdF, Bobigny, France (LD, EK-G, SB, CE, SP, A-CV, SC-Y, KC, VD, PB, SC, and SH); the Department of Epidemiology and Public Health, Rouen University Hospital, Rouen, France (LD); and Département Inter-Hospitalier de Santé Publique, Hôpital Avicenne, Bobigny, AP-HP, France (SC and SH).

² The SU.VI.MAX study is supported by the Direction Générale de la Santé, the Ministère de la Santé, and the Institut Virtuel de Recherche en Santé Publique (groupe cohorte) INSERM.

³ Reprints not available. Address correspondence to S Hercberg, UMR (INSERM/INRA/CNAM/P13), Centre de Recherche en Nutrition Humaine Ile-de-France, 74 rue Marcel Cachin, 93017 Bobigny CEDEX, France. E-mail: hercberg@cnam.fr.

Received November 3, 2006.

Accepted for publication February 8, 2007.

Inclusion criteria

In the cross-sectional analyses, only participants who completed ≥ 3 dietary records before the first clinical examination were eligible ($n = 2596$ men, 3523 women). Among these, 5041 participants had no missing covariables [eg, age, body mass index (BMI), physical activity, tobacco use, level of education, dietary records, or BP measurements]. Finally, 389 participants who reported taking any antihypertensive medications at the first clinical exam were excluded; thus, 1937 men aged 42–63 y and 2715 women aged 35–63 y were included in the present analysis.

The longitudinal analysis is based on the same sample. A total of 1073 participants with hypertension (measured as a SBP ≥ 140 mm Hg or a DBP ≥ 90 mm Hg, antihypertensive medication use, or both) at the first clinical examination were excluded from the present analysis. In the longitudinal analysis, we did not exclude participants who received antihypertensive treatment medication initiated after the first clinical examination. Of the remaining participants, 841 men and 1500 women with available data from the last clinical examination were included in the longitudinal analysis of BP change.

Data collection

The participants' general characteristics were collected by a self-administrated questionnaire at enrollment. Data on education level were coded into 3 categories (primary school, high school, or university or equivalent). Data on smoking status (current smoker, former smoker, or nonsmoker) and habitual physical activity (none or irregular, < 1 h/d, or ≥ 1 h/d) were also obtained from the same questionnaire.

A clinical examination was conducted from 1995 to 1996 and again from 2001 to 2002 for the follow-up clinical exam. At each clinical exam, height, weight and blood pressure were measured. Weight was measured by using an electronic scale with the participants wearing indoor clothing and no shoes. Height was measured under the same conditions to the nearest 0.5 cm by using a wall-mounted stadiometer. BP was measured by using a standardized procedure with a standard mercury sphygmomanometer. BP was taken once from each arm of the participants after they had been lying down for 10 min. The mean of these 2 measurements was used for analyses. If SBP was > 160 mm Hg or DBP was > 100 mm Hg, BP was remeasured after a second rest period of 10 min, and the lowest value was retained. To account for the effect of antihypertensive treatment initiated after the first clinical examination, we used the stepwise correction described by Cui et al (12); increments of 8/4 mm Hg (SBP/DBP), 14/10 mm Hg, and 20/16 mm Hg were added to the SBP and DBP measured at the last clinical exam of participants taking 1, 2, and 3 different antihypertensive medication classes, respectively.

Dietary assessment

Participants were asked to provide 24-h dietary records every 2 mo for a total of 6 records per year. Dietary data were transmitted by participants by using the Minitel Telematic Network. The Minitel was a small terminal widely used in France as an adjunct to the telephone at the beginning of the SU.VI.MAX study in the 1990s. At enrollment, the participants received a small central processing unit specifically designed for the study, which contained specialized software allowing participants to fill out a computerized dietary record off-line and subsequently

transmit their data during brief telephone connections. The participants were assisted by the conversational facilities of the software and used an instruction manual for coding food portions. This previously validated reference manual (13) includes photographs of > 250 foods (corresponding to 1000 generic foods) represented in 3 different portion sizes. The participants could also choose from 2 intermediate or 2 extreme portions, for a total of 7 different possible portion sizes.

Nutrient, vitamin, mineral, and alcohol intakes were estimated by using food-composition tables validated for the French population (14). Each course was divided and categorized into food groups by using a recipe table. For each participant, only the dietary records completed before the first clinical examination (between inclusion periods in 1994–1995 and 1995–1996) were included for the present analysis and were reported as average intakes.

Dietary patterns

Five dietary exposure variables were studied. We examined 3 main characteristics of the DASH diet: fruit and vegetables (excluding potatoes and legumes), dairy products (including milk, cheese, yogurt, and other dairy products), and the healthy fat pattern as defined by the Keys score (15). We also studied 2 different hypothesis-oriented dietary patterns scores that were adapted from the DASH eating plan.

The Keys score is calculated by the following equation:

$$\text{Keys score} = 1.35 \times (2S - P) + 1.5 \times C^{0.5} \quad (1)$$

where S and P are the percentage of energy from saturated fat and polyunsaturated fat, respectively, and C is dietary cholesterol (in mg/1000 kcal). A healthy fat intake pattern is reflected by a lower Keys score.

The 2 scores adapted from the DASH eating plan (3) were based on a combined dietary pattern variable (3). The DASH score was created by using a hypothesis-oriented pattern variable as described previously by Schulze et al (16). This score represents the sum of 3 standardized food groups (where the mean = 0 and SD = 1): fruit, vegetables, and dairy products, which results in a graded score that essentially reflects a dietary pattern rich in these types of foods. A "DASH plus Keys score" was created by adding the standardized Keys score to the DASH score such that it reflects the DASH diet and a healthy fat pattern.

Statistical analysis

We first performed a cross-sectional analysis to study the relation between diet and BP measured at the first clinical examination using a generalized linear model. We then performed a longitudinal analysis to study the relation between diet and BP change measured at the first and last clinical examination. Specific quartiles were calculated for each sex and P for linear trend was performed by using dietary intakes as continuous variables. Two adjustment models were used. In addition to the dietary exposure variable study (eg, fruit and vegetables, DASH score, etc.), model 1 included age, sex, group (treatment compared with placebo), total energy intake (excluding alcohol), and number of dietary records completed. In model 1, only 1 of the 5 dietary variables studied was included in the model at each time. Model 2 included all adjustments made in model 1 plus tobacco use, alcohol (specific tertile by sex), physical activity, educational

level, BMI (<18.5, 18.5–25, 25–30, or ≥ 30), and dietary sodium intake (except table salt). In model 2, results were adjusted by using other dietary variables. Thus, 3 analyses were performed by using an adjustment of model 2. The first model included intakes of fruit and vegetables, intake of dairy products, and Keys score; the second model included the DASH score and the Keys score; and, finally, the third model included only the DASH plus Keys score. The longitudinal analysis was further adjusted by BP measured (SBP or DBP) at the first clinical examination.

To assess the effect of the step-wise correction of BP on results, we performed a sensitivity analysis using 3 other strategies to account for antihypertensive treatment. Strategy 1 (S1) used no correction of BP, strategy 2 (S2) used other correction of BP on the basis of an analysis of censored values suggested by Levy et al (17), and strategy 3 (S3) excluded 139 participants with an antihypertensive treatment initiated between clinical examinations and thus was performed on the remaining 2212 participants.

All statistical analyses were performed with SAS software (version 8.02; SAS Institute, Cary, NC) by using standard procedures. Statistical significance was judged at $\alpha < 0.05$.

RESULTS

Descriptive statistics

Participants who were excluded from the cross-sectional analysis were more likely to be women (61.7% of excluded participants compared with 58.4% of included participants; $P < 0.0002$), to be smokers (17.9% compared with 13.2%; $P < 0.05$), and to have a higher BMI (39.3% compared with 34% with BMI ≥ 25 ; $P < 0.0001$). Of the participants with available data at the first clinical examination ($n = 5041$), 29.0% had high BP levels (SBP ≥ 140 mm Hg or DBP ≥ 90 mm Hg or antihypertensive treatment). Among those, 7.8% were taking antihypertensive medications. The participants without treated hypertension who were included in the cross-sectional analysis ($n = 4652$) had a mean (\pm SD) SBP of 123 ± 14.2 mm Hg and a mean DBP of 79 ± 9.1 mm Hg. Of these participants, 55% had completed ≥ 6 dietary records. The description of the population included in the cross-sectional analysis is shown in **Table 1**.

High fruit and vegetable consumption was associated with a higher educational level (47% of participants who attended college were in the highest intake quartile compared with 37% who were in the lowest quartile; $P < 0.0001$). The participants with higher fruit and vegetable consumption also tended to smoke less (9% compared with 19%, respectively; $P < 0.0001$), drink less alcohol (15 g/d compared with 19.6 g/d, respectively; $P < 0.0001$), and engage in more physical activity (22% compared with 28% who performed no or irregular physical activity; $P < 0.01$). Higher fruit and vegetable consumption was also associated with a lower Keys score (Spearman $r = -0.27$, $P < 0.0001$) and with a higher consumption of dairy products (Spearman $r = 0.19$, $P < 0.0001$).

High dairy product consumption was associated with lower current tobacco use (9% compared with 19%; $P < 0.0001$) and lower alcohol intake (14 g/d compared with 22 g/d; $P < 0.0001$). No significant associations were observed between the Keys score and variables other than fruit and vegetable intakes (results not tabulated).

TABLE 1

Description of the study population included in the cross-sectional analysis by sex ($n = 4652$)¹

	Men	Women	P ²
Number	1937	2715	0.64
Treated group (%)	50.7	50.1	< 0.0001
Age (y)	52.7 \pm 4.7 ³	47.9 \pm 6.5	< 0.0001
Education level			
Primary	23.6	18.0	< 0.0001
High school	34.7	40.6	< 0.0001
College	41.7	41.4	< 0.0001
Tobacco (%)			
Nonsmoker	35.6	57.3	< 0.0001
Former smoker	51.5	29.2	< 0.0001
Smoker	12.9	13.5	< 0.0001
Alcohol intake (g/d)	28.1 \pm 24.5	10.4 \pm 13	< 0.0001
Physical activity (%)			
None	22.1	26.6	< 0.0001
<1 h walking/d	24.6	35.2	< 0.0001
> 1 h walking/d	53.3	38.2	< 0.0001
BMI, kg/m ² (%)			
<25	48.8	78.2	< 0.0001
25–30	45.0	16.4	< 0.0001
>30	6.1	5.4	< 0.0001
Untreated hypertension (%) ⁴	36.3	13.6	< 0.0001
Intake			
Fruit and vegetables (g)	448.4 \pm 211.6	413.9 \pm 178	< 0.0001
Fruit (g)	204.6 \pm 148.3	182.2 \pm 117.7	< 0.0001
Vegetables (g)	196.2 \pm 100.6	186.8 \pm 92.3	< 0.0001
Dairy products (g)	270.1 \pm 173.7	259.8 \pm 174.1	< 0.05
Keys score	56.9 \pm 9.9	58.3 \pm 9.8	< 0.0001
DASH score	0.0 \pm 1.97	0.0 \pm 2.01	
DASH + Keys score	0.0 \pm 2.4	0.0 \pm 2.4	

¹ DASH, Dietary Approaches to Stop Hypertension. Subjects reporting antihypertensive treatment at first clinical examination were not included in this analysis.

² Chi-square for qualitative variables and *t* test for quantitative variables.

³ $\bar{x} \pm$ SD (all such values).

⁴ Systolic blood pressure ≥ 140 mm Hg or diastolic blood pressure ≥ 90 mm Hg.

Cross-sectional analysis of blood pressure measurements taken at the first clinical examination and dietary patterns

High fruit and vegetable consumption was associated with lower BP at the first clinical examination, as shown in **Table 2** (model 1 in a comparison of the 4th with the 1st quartile: SBP: -1.6 mm Hg, P for trend < 0.02 ; DBP: -1.0 mm Hg, P for trend < 0.005). No significant associations were observed for dairy product consumption or a dietary fat pattern as defined by the Keys score. The DASH score was associated with lower BP (model 1 in a comparison of the 4th with the 1st quartile: SBP: -1.5 mm Hg, P for trend < 0.004 ; DBP: -1.2 mm Hg, P for trend < 0.0002). This association was not strengthened for the combined DASH plus Keys score. Results did not substantially change after further adjustment (ie, model 2).

When comparing results by sex (results not tabulated), fruit and vegetable consumption was associated with a lower BP in men (SBP in a comparison of the 4th with the 1st quartile: -1.7

TABLE 2Relation between baseline food consumption and adjusted blood pressure at first clinical examination in 4652 men and women¹

Food and quartile median	SBP				DBP			
	Model 1 ²		Model 2 ³		Model 1 ²		Model 2 ³	
	Difference	<i>P</i> for trend	Difference	<i>P</i> for trend	Difference	<i>P</i> for trend	Difference	<i>P</i> for trend
	<i>mm Hg</i>		<i>mm Hg</i>		<i>mm Hg</i>		<i>mm Hg</i>	
Fruit and vegetables								
220 g	Reference		Reference		Reference		Reference	
350 g	-0.5 (-1.6, 0.6) ⁴		-0.4 (-1.5, 0.6)		-0.1 (-0.8, 0.6)		-0.1 (-0.8, 0.6)	
466 g	-1.1 (-2.2, 0.0)		-0.8 (-1.9, 0.3)		-1.0 (-1.7, -0.3)		-0.8 (-1.5, -0.1)	
646 g	-1.6 (-2.7, -0.5)	< 0.02	-1.4 (-2.6, -0.2)	< 0.02	-1.0 (-1.8, -0.3)	< 0.005	-0.9 (-1.7, -0.2)	< 0.002
Dairy products								
83 g	Reference		Reference		Reference		Reference	
180 g	-0.9 (-1.9, 0.2)		-0.8 (-1.8, 0.3)		-0.4 (-1.1, 0.2)		-0.4 (-1.1, 0.2)	
285 g	-0.4 (-1.5, 0.6)		-0.5 (-1.6, 0.5)		-0.3 (-1.0, 0.3)		-0.5 (-1.2, 0.2)	
462 g	-1.3 (-2.3, -0.2)	0.18	-1.2 (-2.3, -0.1)	0.16	-1.0 (-1.7, -0.3)	< 0.02	-1.1 (-1.8, -0.4)	< 0.004
Keys score								
46	Reference		Reference		Reference		Reference	
55	0.6 (-0.5, 1.7)		0.0 (-1.0, 1.1)		0.4 (-0.3, 1.1)		0.0 (-0.7, 0.6)	
60	1.1 (0.0, 2.1)		0.4 (-0.7, 1.4)		0.7 (0.1, 1.4)		0.3 (-0.4, 0.9)	
68	0.7 (-0.3, 1.8)	0.39	-0.2 (-1.3, 0.8)	0.81	0.5 (-0.2, 1.2)	0.70	-0.1 (-0.8, 0.5)	0.45
DASH score								
-2.16	Reference		Reference		Reference		Reference	
-0.79	-0.4 (-1.5, 0.7)		-0.3 (-1.3, 0.8)		-0.4 (-1.1, 0.3)		-0.4 (-1.1, 0.2)	
0.38	-0.6 (-1.7, 0.5)		-0.5 (-1.6, 0.6)		-0.6 (-1.4, 0.1)		-0.7 (-1.4, 0.0)	
2.29	-1.5 (-2.6, -0.3)	< 0.004	-1.5 (-2.7, -0.3)	< 0.004	-1.2 (-2.0, -0.5)	< 0.0002	-1.4 (-2.1, -0.7)	< .0001
DASH + Keys score								
-2.63	Reference		Reference		Reference		Reference	
-0.93	0.0 (-1.1, 1.1)		0.2 (-0.8, 1.3)		0.0 (-0.7, 0.7)		0.0 (-0.6, 0.7)	
0.53	-0.8 (-1.9, 0.2)		-0.6 (-1.6, 0.5)		-0.7 (-1.4, 0.0)		-0.6 (-1.3, 0.1)	
2.72	-1.6 (-2.7, -0.5)	< 0.003	-1.3 (-2.5, -0.2)	< 0.02	-1.3 (-2.0, -0.6)	< 0.0003	-1.2 (-2.0, -0.5)	< 0.0006

¹ SBP, systolic blood pressure; DBP, diastolic blood pressure; DASH, Dietary Approaches to Stop Hypertension. All analyses used General Linear Model, (Proc GLM). *P* for trend is calculated for continuous variables.

² Adjusted for age, sex, group (treatment or placebo), total energy intake (excluding alcohol), and number of dietary records completed.

³ Adjusted for all variables in model 1 + tobacco, alcohol, physical activity, education level, BMI, dietary sodium, and other dietary variables (fruit and vegetables, dairy products, and Keys score) if they were not part of a score included in the model.

⁴ Difference from first quartile; 95% CI in parentheses (all such values).

mm Hg, *P* for trend < 0.20; DBP in a comparison of the 4th with the 1st quartile: -1.2 mm Hg, *P* for trend < 0.08) and in women (SBP in a comparison of the 4th with the 1st quartile: -1.6 mm Hg, *P* for trend < 0.03; DBP in a comparison of the 4th with the 1st quartile: -1.0 mm Hg, *P* for trend < 0.02). Relations were also similar for the DASH score for men (SBP in a comparison of the 4th with the 1st quartile: -1.8 mm Hg, *P* for trend < 0.02; DBP in a comparison of the 4th with the 1st quartile: -1.6 mm Hg, *P* for trend < 0.002 mm Hg) and women (SBP in a comparison of the 4th with the 1st quartile: -1.3 mm Hg, *P* for trend < 0.06; DBP in a comparison of the 4th with the 1st quartile: -1.8 mm Hg, *P* for trend < 0.0008). Dairy product consumption was associated with lower BP in men (SBP in a comparison of the 4th with the 1st quartile: -2.6 mm Hg, *P* for trend < 0.04; DBP in a comparison of the 4th with the 1st quartile: -1.8 mm Hg, *P* for trend < 0.007), but not in women (interaction between sex and dairy product for SBP: *P* < 0.03; that for DBP: *P* < 0.05).

Longitudinal analysis on blood pressure change and diet

Normotensive participants who did not attend the last clinical examination were less physically active (40% compared with 45% for those with ≥1 h activity/d; *P* < 0.001) and consumed less fruit (183 g/d compared with 197 g/d; *P* < 0.002).

The median time between the first and last clinical examinations was 5.4 y (range: 4.4–6.4 y). The mean (±SD) SBP increased by 9.3 ± 11.7 mm Hg and the mean DBP by 4.5 ± 8.3 mm Hg. Of those included in the longitudinal analysis, 26.5% were newly diagnosed with hypertension (SBP ≥140 mm Hg or DBP ≥90 mm Hg, antihypertensive medication use, or both) at the last clinical examination, and 5.6% were receiving treatment. The relations between baseline food dietary characteristics and adjusted BP change between the first and last clinical examination are presented in **Table 3**.

High fruit and vegetable consumption was associated with a smaller increase in BP (model 1 in a comparison of the 4th with the

TABLE 3

Relation between baseline food consumption and adjusted change in blood pressure between the first and last clinical examination in 2341 men and women¹

Food and quartile median	SBP				DBP			
	Model 1 ²		Model 2 ³		Model 1		Model 2	
	Difference in change	<i>P</i> for trend	Difference in change	<i>P</i> for trend	Difference in change	<i>P</i> for trend	Difference in change	<i>P</i> for trend
	<i>mm Hg</i>		<i>mm Hg</i>		<i>mm Hg</i>		<i>mm Hg</i>	
Fruit and vegetables	Reference		Reference		Reference		Reference	
228 g	Reference		Reference		Reference		Reference	
348 g	-0.7 (-2.1, 0.6) ⁴		-0.7 (-2.0, 0.6)		-0.3 (-1.2, 0.7)		-0.2 (-1.1, 0.7)	
467 g	-1.6 (-2.9, -0.3)		-1.4 (-2.7, 0.0)		-0.5 (-1.4, 0.4)		-0.4 (-1.3, 0.6)	
642 g	-2.2 (-3.6, -0.8)	< 0.005	-2.1 (-3.6, -0.7)	< 0.004	-0.8 (-1.7, 0.2)	< 0.04	-0.7 (-1.7, 0.3)	< 0.03
Dairy products	Reference		Reference		Reference		Reference	
84 g	Reference		Reference		Reference		Reference	
181 g	0.2 (-1.1, 1.5)		0.4 (-0.9, 1.7)		0.0 (-0.9, 0.9)		0.0 (-0.9, 0.9)	
284 g	0.1 (-1.3, 1.4)		0.2 (-1.1, 1.5)		-0.1 (-1.0, 0.8)		-0.1 (-1.0, 0.8)	
456 g	0.1 (-1.2, 1.4)	0.70	0.1 (-1.2, 1.5)	0.56	-0.2 (-1.1, 0.7)	0.46	-0.2 (-1.2, 0.7)	0.34
Keys score	Reference		Reference		Reference		Reference	
46	Reference		Reference		Reference		Reference	
55	0.5 (-0.7, 1.8)		0.3 (-1.0, 1.5)		0.5 (-0.4, 1.4)		0.4 (-0.5, 1.3)	
61	0.1 (-1.2, 1.4)		-0.3 (-1.6, 1.0)		0.3 (-0.6, 1.2)		0.2 (-0.7, 1.1)	
69	1.1 (-0.1, 2.4)	0.97	0.2 (-1.1, 1.6)	0.70	0.6 (-0.3, 1.4)	0.63	0.3 (-0.7, 1.2)	0.52
DASH score	Reference		Reference		Reference		Reference	
-2.17	Reference		Reference		Reference		Reference	
-0.76	-0.2 (-1.5, 1.2)		-0.1 (-1.4, 1.2)		0.4 (-0.5, 1.3)		0.5 (-0.4, 1.4)	
0.48	-1.1 (-2.4, 0.3)		-1.0 (-2.4, 0.3)		0.4 (-0.5, 1.4)		0.4 (-0.5, 1.4)	
2.66	-1.9 (-3.4, -0.5)	< 0.003	-2.1 (-3.6, -0.7)	< 0.002	-0.5 (-1.5, 0.5)	< 0.04	-0.6 (-1.6, 0.4)	< 0.02
DASH + Keys score	Reference		Reference		Reference		Reference	
-2.63	Reference		Reference		Reference		Reference	
-0.95	-1.0 (-2.3, 0.3)		-0.8 (-2.1, 0.5)		0.2 (-0.7, 1.1)		0.3 (-0.6, 1.2)	
0.56	-1.8 (-3.1, -0.4)		-1.7 (-3.1, -0.4)		-0.1 (-1.0, 0.9)		0.0 (-1.0, 0.9)	
2.74	-1.8 (-3.2, -0.5)	< 0.005	-1.8 (-3.2, -0.5)	< 0.006	-0.5 (-1.4, 0.4)	0.08	-0.6 (-1.5, 0.4)	< 0.06

¹ SBP, systolic blood pressure; DBP, diastolic blood pressure; DASH, Dietary Approaches to Stop Hypertension. All analyses were performed by using the General Linear Model (Proc GLM). *P* for trend is calculated for continuous variables.

² Adjusted for age, sex, group (treatment vs placebo), total energy intake (excluding alcohol), number of dietary records completed, and SBP or DBP at first clinical examination.

³ Adjusted for all variables in model 1 + tobacco, alcohol, physical activity, education level, BMI, dietary sodium, other dietary variables (fruit and vegetables, dairy products, and Keys score) if they are not part of a score included in the model, and SBP or DBP at first clinical examination.

⁴ Difference from first quartile; 95% CI in parentheses (all such values).

1st quartile: SBP: -2.2 mm Hg, *P* for trend < 0.005; DBP: -0.8 mm Hg, *P* for trend < 0.04). No significant associations were observed with dairy product consumption or the Keys score.

The DASH score was associated with a smaller increase in BP (Model 1 in a comparison of the 4th with the 1st quartile: SBP: -1.9 mm Hg, *P* for trend < 0.003; DBP: -0.5 mm Hg, *P* for trend < 0.04). This relation was similar for the DASH + Keys score. Results were only slightly changed by further adjustment (model 2).

A separate analysis by sex (results not tabulated) showed a similar relation between fruit and vegetable consumption and BP change in men (model 1 in a comparison of the 4th with the 1st quartile: SBP: -2.5 mm Hg, *P* for trend < 0.01; DBP: -0.6 mm Hg, *P* for trend < 0.05) and women (model 1 in a comparison of the 4th with the 1st quartile: SBP: -1.8 mm Hg, *P* for trend < 0.13; DBP: -0.8 mm Hg, *P* for trend < 0.33). A high DASH score was associated with a smaller increase in BP in men (model 1 in a comparison of the 4th with the 1st quartile: SBP: -2.7 mm

Hg, *P* for trend < 0.03; DBP: -0.8 mm Hg, *P* for trend < 0.12) and women (model 1 in a comparison of the 4th with the 1st quartile: SBP: -1.5 mm Hg, *P* for trend < 0.06; DBP: -0.3 mm Hg, *P* for trend < 0.17). The relation between fruit and vegetable consumption and BP change remained after further adjustment for magnesium and potassium intakes (data not shown).

Sensitivity analysis

Results were only slightly changed between strategies used to account for antihypertensive treatment. Eg, for model 1 for fruit and vegetable consumption, the difference in SBP increase between the 4th and the 1st quartile ranged from -2.1 for S1 (*P* for trend < 0.003) to -1.7 for S3 (*P* for trend < 0.007).

DISCUSSION

In our study, high fruit and vegetable consumption was associated with lower BP and a lower increase in BP with aging. This

relation was significant among participants who reached the current daily fruit and vegetable intake recommendation of >400 g (18) (around 5 portions) and was even stronger among those with higher consumption. An association between BP at first clinical examination and dairy product consumption was only significant in the men. No significant associations were observed between BP or BP change and a healthy fat dietary pattern. Associations observed for the DASH score were similar to those observed for fruit and vegetable consumption.

The associations between fruit and vegetable consumption, BP, and BP change are consistent with results from previous studies. In cross-sectional analyses, fruit and vegetable consumption has been shown to be associated with lower BP (19–22). Furthermore, previous cohort studies reported a relation between BP change and consumption of fruit, vegetables, or both (23–25). For instance, in the Chicago Western Electric study, men who consumed >42 cups/mo of fruit or vegetables compared with those who consumed <14 cups/mo had a lower average annual increase in SBP (fruit: -0.28 mm Hg; vegetable: -0.24 mm Hg) after 7 y of follow-up (1959–1966) (23). However, note that information regarding antihypertensive treatment was not available in this study, so we cannot exclude the possibility that high fruit and vegetable consumers who, although possibly more health-conscious, could have been previously treated for hypertension. A similar relation has been observed in another age group. In an 8-y follow-up study, higher fruit and vegetable consumption among children aged 3–6-y-old at baseline was found to be associated with a lower increase in BP (25). Our results, combined with the results from other cohort studies, suggest that in addition to a short-term reduction in BP, fruit and vegetable consumption could prevent an increase of BP with age (26). This effect could partly explain the lower risk of stroke (27, 28) and coronary heart disease (29) associated with higher high fruit and vegetable consumption observed in cohort studies. Antioxidants have been hypothesized to affect BP arterial stiffness (30). However, in the SU.VI.MAX study, daily antioxidant supplementation was found to have no effect on the risk of hypertension compared with placebo (31), suggesting that long-term changes in blood pressure may not be explained by antioxidant activity alone but by other fruit and vegetable compounds. Furthermore, the relation between fruit and vegetable consumption and BP change was still significant after adjustment for dietary magnesium and potassium (data not shown). Therefore, this relation may be explained by other components in vegetables such as fibers or a combined effect of fruit and vegetable components. It is also likely that the association observed in cohort studies may be explained by confounding factors. High fruit and vegetable consumers often have healthier behaviors, such as high physical activity, low alcohol intake, or abstention from smoking, which may not be completely controlled when adjusting for confounding factors.

Our study showed little evidence of a relation between dairy product consumption and BP. This result is in contradiction with previous results (24, 25, 32–34). Calcium is suspected to modulate BP (32), and calcium or dairy product consumption have been shown to be associated with lower BP in observational and experimental studies (33, 34) as well as with a lower increase in BP with age (24, 25). In contrast, in our study, dairy product consumption was associated with BP measured at the first clinical examination only among men and it was not related to BP change in general. The high average calcium intake by women (918 mg/d) in our study compared with other studies [for example,

450 mg/d in the DASH study control diet (35)] may explain the lack of relation observed between dairy product consumption and BP. However, an association was observed at the first clinical examination in men despite a calcium intake only slightly lower than that of women (93 mg/d less after adjustment for energy intake).


No significant associations between the Keys score and BP or BP change were observed in our study, suggesting that there is no significant effect of fatty acid consumption on BP. These results are in agreement with those of the Health Professionals Follow-up Study which found no relation between fatty acid consumption and risk of incident hypertension (36). In contrast, few epidemiologic studies show conflicting results. A low Keys score was associated with a lower increase in BP in the Western Electric study (37), whereas low fatty acid consumption was associated with a lower risk of hypertension incidence in a cohort study (38) and a lower BP in cross-sectional studies (39, 40). In our analysis, the poor relation observed between the Keys score and BP or BP change explained why adding the Keys score to the DASH score did not strengthen the relation with BP although decreased total fat and low saturated fat intake is one of the main components of the DASH diet.

A high DASH score was associated with a lower BP at the first clinical examination and a lower increase in BP with aging. These results are consistent with those of the European Prospective Investigation into Cancer and Nutrition Potsdam study, where a DASH dietary pattern score was associated with a lower risk of incident hypertension over 2–4 y of follow-up (16). The BP-reducing effect of a diet based on the DASH dietary pattern over the short term has also been confirmed in several intervention studies (3–6). This effect was lower when patients purchased their own food according to recommendations than when they strictly received a control diet (41, 42).

In our study, the associations between the DASH score and BP as well as BP change were not significantly stronger than the association between fruit and vegetable consumption and BP or BP change. These results suggest that a combined dietary pattern that is similar to the DASH diet may not be more effective in preventing hypertension than is fruit and vegetable consumption alone; however, results of other studies are not consistent with this hypothesis. The DASH study showed that the combined effect of a diet rich in fruit, vegetables, and dairy products and low in fat was more effective in the short term in reducing SBP than was high fruit and vegetable consumption alone (3). In addition, cohort studies that included additional diet characteristics, such as high fish, low meat (23), and high dairy (25) consumption and low Keys score (37) were shown to be associated with a lower BP increase, which suggests that other components of the DASH diet may be associated with the lower BP change.

Our study has its strengths and limitations. First, our study included a large sample of participants from a free-living population and with large diet diversity, even though participants were recruited on a voluntary basis (11). In addition, the present study included a detailed assessment of dietary intakes; >6 dietary records were obtained for 55% of the participants included in the cross-sectional analysis. One limitation of the present study was that the correction of BP with antihypertensive treatment may be only an approximate measure. However, sensitivity analyses showed that the results were only slightly changed when we did not correct for hypertensive treatment, excluded treated participants, or used another correction. Finally, despite the fact that the number of participants lost to follow-up was relatively low in the

SU.VI.MAX study (10), a large number of participants were excluded in the present analysis because not all participants provided enough dietary records or were present at all clinical examinations.

In conclusion, our results suggest that a dietary pattern rich in fruit and vegetable consumption could slow the increase in BP with aging. These results were also observed among dietary patterns based on the DASH diet and provide additional support for such dietary recommendations for the prevention of hypertension. 

The authors' contributions were as follows—LD: data analysis, interpretation of the data, and writing of the manuscript; EK-G, SC, CE, SP, A-CV, SC-Y, KC, VD, and PB: assisted with interpretation of data and critical revision of the manuscript. SB and SH: contributed to the experimental design, collection of data, interpretation of data, and critical revision of the manuscript. None of the authors had any personal or financial conflicts of interest.

REFERENCES

1. Wolf-Maier K, Cooper RS, Banegas JR, et al. Hypertension prevalence and blood pressure levels in 6 European countries, Canada, and the United States. *JAMA* 2003;289:2363–9.
2. Whelton PK, He J, Muntner P. Prevalence, awareness, treatment and control of hypertension in North America, North Africa and Asia. *J Hum Hypertens* 2004;18:545–51.
3. Appel LJ, Moore TJ, Obarzanek E, et al. A clinical trial of the effects of dietary patterns on blood pressure. DASH Collaborative Research Group. *N Engl J Med* 1997;336:1117–24.
4. Sacks FM, Svetkey LP, Vollmer WM, et al. Effects on blood pressure of reduced dietary sodium and the Dietary Approaches to Stop Hypertension (DASH) diet. DASH-Sodium Collaborative Research Group. *N Engl J Med* 2001;344:3–10.
5. Miller ER III, Erlinger TP, Young DR, et al. Results of the Diet, Exercise, and Weight Loss Intervention Trial (DEW-IT). *Hypertension* 2002;40:612–8.
6. Nowson CA, Worsley A, Margetison C, et al. Blood pressure response to dietary modifications in free-living individuals. *J Nutr* 2004;134:2322–9.
7. Fung TT, Stampfer MJ, Manson JE, et al. Prospective study of major dietary patterns and stroke risk in women. *Stroke* 2004;35:2014–9.
8. Hu FB, Rimm EB, Stampfer MJ, et al. Prospective study of major dietary patterns and risk of coronary heart disease in men. *Am J Clin Nutr* 2000;72:912–21.
9. Chobanian AV, Bakris GL, Black HR, et al. Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. *Hypertension* 2003;42:1206–52.
10. Hercberg S, Galan P, Preziosi P, et al. The SU.VI.MAX Study: a randomized, placebo-controlled trial of the health effects of antioxidant vitamins and minerals. *Arch Intern Med* 2004;164:2335–42.
11. Hercberg S, Preziosi P, Briancon S, et al. A primary prevention trial using nutritional doses of antioxidant vitamins and minerals in cardiovascular diseases and cancers in a general population: the SU.VI.MAX study—design, methods, and subject characteristics. *Supplementation en Vitamines et Minéraux Antioxydants. Control Clin Trials* 1998;19:336–51.
12. Cui JS, Hopper JL, Harrap SB. Antihypertensive treatments obscure familial contributions to blood pressure variation. *Hypertension* 2003;41:207–10.
13. Le Moullec N, Deheeger M, Preziosi P, et al. Validation du manuel-photos utilisé pour l'enquête alimentaire de l'étude SU. VI.MAX. *Cah Nutr Diet* 1996;31:399–418.
14. Hercberg S (coordinator). Tables de composition des aliments SU.VI. MAX. Paris, France: Economica, 2005 (in French).
15. Anderson JT, Jacobs DR Jr, Foster N, et al. Scoring systems for evaluating dietary pattern effect on serum cholesterol. *Prev Med* 1979;8:525–37.
16. Schulze MB, Hoffmann K, Kroke A, Boeing H. Risk of hypertension among women in the EPIC-Potsdam Study: comparison of relative risk estimates for exploratory and hypothesis-oriented dietary patterns. *Am J Epidemiol* 2003;158:365–73.
17. Levy D, DeStefano AL, Larson MG, et al. Evidence for a gene influencing blood pressure on chromosome 17. Genome scan linkage results for longitudinal blood pressure phenotypes in participants from the Framingham heart study. *Hypertension* 2000;36:477–83.
18. World Health Organization. WHO Fruit and vegetable promotion initiative—Report of the meeting, Geneva 25–27 august 2003. Geneva, Switzerland: World Health Organization, 2003.
19. Psaltopoulou T, Naska A, Orfanos P, et al. Olive oil, the Mediterranean diet, and arterial blood pressure: the Greek European Prospective Investigation into Cancer and Nutrition (EPIC) study. *Am J Clin Nutr* 2004;80:1012–8.
20. Ascherio A, Hennekens C, Willett WC, et al. Prospective study of nutritional factors, blood pressure, and hypertension among US women. *Hypertension* 1996;27:1065–72.
21. Alonso A, de la Fuente C, Martin-Arnau AM, et al. Fruit and vegetable consumption is inversely associated with blood pressure in a Mediterranean population with a high vegetable-fat intake: the Seguimiento Universidad de Navarra (SUN) Study. *Br J Nutr* 2004;92:311–9.
22. Beitz R, Mensink GB, Fischer B. Blood pressure and vitamin C and fruit and vegetable intake. *Ann Nutr Metab* 2003;47:214–20.
23. Miura K, Greenland P, Stamler J, et al. Relation of vegetable, fruit, and meat intake to 7-year blood pressure change in middle-aged men: the Chicago Western Electric Study. *Am J Epidemiol* 2004;159:572–80.
24. Steffen LM, Kroenke CH, Yu X, et al. Associations of plant food, dairy product, and meat intakes with 15-y incidence of elevated blood pressure in young black and white adults: the Coronary Artery Risk Development in Young Adults (CARDIA) Study. *Am J Clin Nutr* 2005;82:1169–77.
25. Moore LL, Singer MR, Bradlee ML, et al. Intake of fruits, vegetables, and dairy products in early childhood and subsequent blood pressure change. *Epidemiology* 2005;16:4–11.
26. Miura K, Nakagawa H. Can dietary changes reduce blood pressure in the long term? *Curr Opin Nephrol Hypertens* 2005;14:253–7.
27. Dauchet L, Amouyel P, Dallongeville J. Fruit and vegetable consumption and risk of stroke: a meta-analysis of cohort studies. *Neurology* 2005;65:1193–7.
28. He FJ, Nowson CA, MacGregor GA. Fruit and vegetable consumption and stroke: meta-analysis of cohort studies. *Lancet* 2006;367:320–6.
29. Dauchet L, Amouyel P, Hercberg S, Dallongeville J. Fruit and vegetable consumption and risk of coronary heart disease: a meta-analysis of cohort studies. *J Nutr* 2006;136:2588–93.
30. Czernichow S, Blacher J, Hercberg S. Antioxidant vitamins and blood pressure. *Curr Hypertens Rep* 2004;6:27–30.
31. Czernichow S, Bertrais S, Blacher J, et al. Effect of supplementation with antioxidants upon long-term risk of hypertension in the SU.VI.MAX study: association with plasma antioxidant levels. *J Hypertens* 2005;23:2013–8.
32. Zemel MB. Calcium modulation of hypertension and obesity: mechanisms and implications. *J Am Coll Nutr* 2001;20:428S–35S.
33. Birkett NJ. Comments on a meta-analysis of the relation between dietary calcium intake and blood pressure. *Am J Epidemiol* 1998;148:223–8.
34. Miller GD, DiRienzo DD, Reusser ME, McCarron DA. Benefits of dairy product consumption on blood pressure in humans: a summary of the biomedical literature. *J Am Coll Nutr* 2000;19:147S–64S.
35. Vogt TM, Appel LJ, Obarzanek E, et al. Dietary Approaches to Stop Hypertension: rationale, design, and methods. DASH Collaborative Research Group. *J Am Diet Assoc* 1999;99:S12–8.
36. Ascherio A, Rimm EB, Giovannucci EL, et al. A prospective study of nutritional factors and hypertension among US men. *Circulation* 1992;86:1475–84.
37. Stamler J, Liu K, Ruth KJ, Pryer J, Greenland P. Eight-year blood pressure change in middle-aged men: relationship to multiple nutrients. *Hypertension* 2002;39:1000–6.
38. Zheng ZJ, Folsom AR, Ma J, et al. Plasma fatty acid composition and 6-year incidence of hypertension in middle-aged adults: the Atherosclerosis Risk in Communities (ARIC) Study. *Am J Epidemiol* 1999;150:492–500.
39. Salonen JT. Dietary fats, antioxidants and blood pressure. *Ann Med* 1991;23:295–8.
40. Cambien F, Warnet JM, Vernier V, et al. An epidemiologic appraisal of the associations between the fatty acids esterifying serum cholesterol and some cardiovascular risk factors in middle-aged men. *Am J Epidemiol* 1988;127:75–86.
41. Appel LJ, Champagne CM, Harsha DW, et al. Effects of comprehensive lifestyle modification on blood pressure control: main results of the PREMIER clinical trial. *JAMA* 2003;289:2083–93.
42. Pickering TG. Lifestyle modification and blood pressure control: is the glass half full or half empty? *JAMA* 2003;289:2131–2.