

Eight-Year Blood Pressure Change in Middle-Aged Men

Relationship to Multiple Nutrients

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Abstract—Relationships of nutrients, alcohol intake, and change in weight to change in blood pressure over 8 years in 1714 employed middle-aged men from the Chicago Western Electric Study were explored. At first and second annual examinations, 2 in-depth interviews were performed to assess usual intake of foods and beverages during the preceding 28 days. Annual follow-up data through examination year 9 were used to determine change in weight and blood pressure. Averages of nutrients from 2 interviews were related to annual blood pressure change from baseline by use of the Generalized Estimating Equation, with control for confounders. In analyses of dietary variables considered individually, total and animal protein; total, saturated, monounsaturated, and polyunsaturated fatty acids; cholesterol; Keys dietary lipid score; calcium; alcohol; and average annual change in weight were positively and significantly related to average annual change in systolic pressure; vegetable protein, total carbohydrate, beta-carotene, and an antioxidant vitamin score based on vitamin C and beta-carotene were inversely and significantly related to average annual change in systolic pressure. In analyses of combinations of dietary factors, cholesterol, Keys score, and alcohol were positively related to change in systolic pressure (eg, Z-scores 2.21, 2.05, and 2.50); vegetable protein and antioxidant index were inversely related to change in systolic and diastolic pressure. Change in weight was directly related to change in systolic and diastolic pressure. These findings support the concept that multiple macro- and micronutrients, alcohol intake, and calorie imbalance relate prospectively to blood pressure change. (*Hypertension*. 2002;39:1000-1006.)

Key Words: blood pressure ■ diet ■ nutrition ■ alcohol ■ body weight ■ population ■ prospective studies

Despite progress in the detection, evaluation, and treatment of high blood pressure (BP), adverse BP levels remain the rule nationally and internationally among adults age ≥ 35 years.¹⁻¹⁰ Prevalence rates of optimal BP (systolic BP [SBP]/diastolic BP [DBP] $\leq 120/\leq 80$ mm Hg) are low, whereas rates of high-normal BP and hypertension are epidemic, resulting in markedly increased risks of major cardiovascular diseases. In contrast, this is not the pattern among young adults, who on average have SBP/DBP within the optimal range.^{5,9} Thus, the root of the epidemic of adverse BP levels is the increase in SBP/DBP that most people experience (in varying degrees) during the decades from youth through middle age.¹⁰

Improved understanding of the causes of this common rise in BP during adulthood—and the application of that understanding for its prevention and control—are essential to end the mass BP problem and the vast burden it engenders. Despite the importance of this problem, prevention of the rise in BP with age was for decades a neglected research area. Few intervention trials were performed, and few population studies measured BP repeatedly for years to assess factors accounting for BP rise.^{1,2,6,10} By 1993, data from these and from related clinical and animal investigations were the basis for the first national

recommendations for primary prevention of high BP; they emphasized reduced salt intake, avoidance and control of obesity and heavy alcohol intake, increased potassium intake, and regular frequent rhythmic exercise.^{2,8-16}

Recently, the 2 Dietary Approaches to Stop Hypertension (DASH) feeding trials demonstrated that an eating pattern modified in several respects from usual US intake—the DASH combination diet—substantially reduced SBP/DBP of both nonhypertensive and hypertensive adults, independent of and additive to the sizable reduction in BP that results from lower salt intake.^{17,18} The DASH combination diet—high in fruits, vegetables, and low-fat and fat-free dairy products, and reduced in fat-containing animal products and sweets—involved multiple modifications in nutrient intake. The design precluded assessment of influences on BP of changes in intake of specific nutrients. Although data from cross-sectional observational studies indicated that several of these nutrients may affect BP, their limitations—including absence of prospective data—precluded clearcut conclusions.¹⁹⁻²² Given the substantial reduction in SBP/DBP with the DASH combination diet, clarification of BP effects of its individual nutrient alterations is now a major challenge, both theoretical and practical.

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Data from the Chicago Western Electric (WE) Study offer a rare opportunity to contribute on this matter: they encompass both high-quality assessment of baseline nutrient intake of a working population of middle-aged men and longitudinal follow-up for 8 years. This paper reports findings on relationships between baseline nutrient intakes of the individual men and their 8-year changes in SBP and DBP.

Methods

The WE Study is a long-term prospective population study principally of coronary heart disease.²³⁻²⁶ In 1957, 3102 men were randomly selected from 5397 male employees, age 40 to 55 years, working for ≥ 2 years at the Hawthorne Works of the WE Company in Chicago; 2080 (67.1%) agreed to participate. Another 27 men served as a pilot group, bringing to 2107 the total number initially examined from October 1957 through December 1958. Ethnic backgrounds, occupations, selection, examination, and follow-up of these men have been described.²³⁻²⁶

Dietary data were obtained at initial and second examinations 1 year apart by 2 nutritionists who used standardized interviews and questionnaires based on Burke's diet history method.²⁷ Baseline dietary data here are means from these 2 examinations (1957-1958 and 1958-1959), to reduce error of classification (the regression dilution bias problem).²⁸⁻³¹ The dietary interview, lasting about 1 hour, asked about usual eating pattern (what, when, and where) on a typical workday and weekend, special diets followed now and previously, and changes in eating habits during the preceding 20 years. This was followed by a detailed cross-check of 195 specific food items to determine number of times in the previous 28 days each food item had been eaten and quantity per serving. As an aid in determining portion sizes, models of commonly used foods and dishes of varying sizes were used for reference. Information was obtained from the dietary department of the company regarding standard portions and types of foods served at the cafeteria. Supplementary information regarding food preparation was obtained from a questionnaire mailed to wives and returned by participants at interview. Information on food preparation was also obtained from neighborhood restaurants and bakeries. When a man reported habitual consumption of a dish not on the list of 195 foods, the recipe was obtained and analyzed into its component parts for nutrient assessment. No data were collected on food supplement use, given its rarity in 1957-1959.

Dietary information was coded by the nutritionists to indicate kinds and quantities of foods and beverages (alcoholic and nonalcoholic) consumed by each participant during the past 28 days. These data were analyzed based on a food table derived from several sources^{23,24} to obtain each man's usual daily caloric intake and consumption of animal and vegetable protein; animal and vegetable fat; total carbohydrates; total saturated fatty acids (SFAs); total unsaturated fatty acids; linoleic acid; linolenic acid; arachidonic acid; cholesterol; calcium; phosphorus; iron; vitamins A, C, and D; thiamine; riboflavin; and niacin. Quantities of linoleic, linolenic, and arachidonic acid were summed to estimate total polyunsaturated fatty acids (PFAs). Subsequently, beta-carotene intake was also estimated, based on data still available on food group intake and on total vitamin A.^{25,26} Data on beta-carotene and vitamin C were used to calculate an antioxidant score for each man, based on his position in the distribution (ie, Z-score) for each of these 2 vitamins; the score calculation was $[(\text{vitamin C Z-score} + \text{beta-carotene Z-score} \div 2) \times 10] + 50$,²⁶ computed with each vitamin expressed as amounts per day and per 1000 kcal.

Men continuing to participate in the study were re-examined annually through 1966, ie, for 7 years after the 2 dietary surveys at the first and second examination. These examinations included measurement of serum cholesterol, a medical history and physical examination, ECG, and other items; methods have been repeatedly described.²³⁻²⁶ BP was measured by study examining physicians by use of standard mercury manometers, with men seated in a quiet room, after a 5-minute rest; Korotkoff phase 1 and 5 were used for SBP and DBP pressure respectively.

Exclusions from the original 2107 participants were made for the following reasons: missing 1 or both dietary assessments (189 men), missing baseline BP (19 men), or missing data on education (107 men). Two cohorts were then identified based on number and timing of BP measurement: the first, totaling 1714 men, was based on exclusion of 78 additional men with only 1 or 2 of the possible 7 annual examinations from 1960 through 1966 (examinations 3 to 9); the second, totaling 1550 men, was based on further exclusions, of 2 men with only 3 of the possible 7 visits from 1960 through 1966, and 162 men with no examinations in 1965 and in 1966 (year 8 and year 9). Identical analyses were performed for both cohorts on relationships of dietary variables to change in SBP and DBP during follow-up years.

For these analyses, use was made of the Generalized Estimating Equation (GEE) method for longitudinal data³² to estimate relationship of baseline dietary factors to average change in SBP or in DBP per year, with adjustment for possible confounders. The relationship of each individual nutrient to BP change was assessed by the coefficient of the cross-product (interaction) term between the nutrient and a time variable, t ($t=0, 1, \dots, 8$). The model also included the time t , the nutrient variable, baseline age, height, education, smoking, alcohol (≥ 2 drinks/day), $\text{age} \times t$, $\text{height} \times t$, $\text{education} \times t$, $\text{smoking} \times t$, $\text{alcohol} \times t$, and change in weight during follow-up. Nutrients were expressed as percent kilocalories or per 1000 kcal. Based on findings in analyses on individual dietary variables and BP change, GEE analyses were done with multiple baseline dietary factors as independent variables, with adjustment for possible confounders. No multivariate analysis included 2 variables that were part-and-whole, eg, animal protein and total protein. To deal with the potential problem of distortion of results in multivariate analyses involving 2 highly correlated variables, analyses were repeated with exclusion of the variable less strongly related to BP change. Results are expressed as coefficients for the relationship of specified units of nutrient (eg, protein as percent kilocalories) to average annual change in SBP, DBP during follow-up; Z-scores are given for coefficients ($Z = \text{coefficient} / \text{standard error}$). Given the paucity of such prospective population-based data, analyses here are appropriately characterized as exploratory, rather than hypothesis testing; Z-scores were used as guides to assess findings; Z-scores of ≥ 1.65 (positive or negative) were deemed relevant in this circumstance.

Results

For the cohort of 1714 men, number of annual examinations ranged from 5 to 9, and examinations over the 9 years totaled 14 186 (8.3 per man); for the cohort of 1550 men, number of annual examinations ranged from 6 to 9, for 13 236 total over the 9 years (8.5 per man). For the 2 cohorts, findings were similar on relationships of dietary variables to change in BP during follow-up. Data are presented here for 1714 men.

Analyses comparing the 1714 included men and the 393 excluded men showed no significant differences for most baseline variables, either dietary or other; probability value, uncorrected for multiple testing, was < 0.05 for percent kilocalories from dietary PFAs (4.0% versus 3.8%), PFA/SFA ratio (0.245 versus 0.236), SBP (134.9 versus 137.4 mm Hg), years of education (11.2 versus 11.7), and cigarettes per day (10.1 versus 11.4).

Descriptive Statistics

Average baseline SBP (134.9 mm Hg) and DBP (87.1 mm Hg) were at high-normal levels, considerably above optimal levels ($\leq 120 / \leq 80$ mm Hg),^{1,6,7} in this cohort of mean age 47.6 years (Table 1). During follow-up, SBP rose 1.0 mm Hg/year on average. As a group, the WE men were overweight at baseline and gained weight over the ensuing

TABLE 1. Descriptive Statistics: Cohort of 1714 Men

Variable	Value
Age, y*	47.6 (4.4)
SBP, mm Hg*	134.9 (18.8)
DBP, mm Hg*	87.1 (11.0)
Average annual change in SBP, mm Hg	1.0 (2.5)
Average annual change in DBP, mm Hg	-0.0 (1.5)
Height, m*	1.72 (0.06)
Weight, kg*	77.7 (10.9)
Body mass index, kg/m ² *	25.5 (3.2)
Average annual change in weight, kg	0.3 (0.7)
Average annual change in body mass index, kg/m ²	0.1 (0.2)
Education, y*	11.2 (2.5)
Smokers, %*	55.7
Cigarettes/day (all)*	10.1 (11.1)
Cigarettes/day (smokers)*	18.2 (8.7)
Alcohol users, %*	85.8
Alcohol/day (all), mL*	16.1 (20.2)
Alcohol/day (users), mL*	18.7 (20.7)
Nondrinkers or <2 drinks/day, %*	83.0
Drinkers of ≥2 drinks/day, %*	17.0
Heart rate/min*	71.7 (11.6)
History of diabetes, %*	1.4
Total energy intake, kcal/day†	3121.3 (779.7)
Total protein, % kcal†	15.0 (1.9)
Animal protein, % kcal†	11.5 (2.1)
Vegetable protein, % kcal†	3.5 (0.6)
Total carbohydrate, % kcal†	38.0 (4.7)
Total fat, % kcal†	42.9 (4.2)
SFA, % kcal†	16.4 (2.2)
Monounsaturated fatty acid, % kcal†	19.6 (2.5)
PFA, % kcal†	4.0 (0.8)
PFA/SFA, % kcal/% kcal†	0.25 (0.06)
Dietary cholesterol, mg/day	731.3 (242.2)
Dietary cholesterol, mg/1000 kcal†	236.3 (60.0)
Keys dietary lipid score,†§	61.8 (7.5)
Vitamin C, mg/day†	101.1 (39.0)
Vitamin C, mg/1000 kcal†	33.3 (12.9)
Beta-carotene, IU/day‡	5559.7 (2765.0)
Beta-carotene, IU/1000 kcal‡	1869.7 (916.6)
Antioxidant score, †¶	50.0 (8.9)
Calcium, mg/day†	1018.8 (446.3)
Calcium, mg/1000 kcal†	326.4 (114.1)

Values are mean±SD or n (%).

*Data from first examination, 1957–1958.

†Mean of data from first and second examinations, 1957–1958 and 1958–1959.

‡Data from second examination, 1958–1959.

§Keys dietary lipid score: 1.35 (2 SFA–PFA)+1.5 C^{1/2}.

¶Antioxidant score: [(vitamin C Z-score+beta-carotene Z-score)/2]×10]+50, with each vitamin expressed as amount/1000 kcal.

years (0.6 lb/year on average). The majority were cigarette smokers. Most (86%) consumed alcohol; 17% reported intake of ≥2 drinks/day.

Reported usual diets were on average high in calories and in percent calories from total fat (43%) and SFAs (16%), with a low ratio (0.25) of polyunsaturates to saturates (Table 1). Cholesterol intake was high on average, as was Keys composite dietary lipid score. Protein intake was mainly of animal, not vegetable, origin—11.5% and 3.5% of calories, respectively. Average intakes of vitamin C, beta-carotene, and calcium were substantial, at levels corresponding to US Recommended Dietary Allowances. For all nutrients, inter-individual differences in intake were considerable, as shown by standard deviations (Table 1), enabling exploration of relationships for these men as individuals between baseline intake levels and changes in SBP/DBP during follow-up. No data are available on intakes of salt (NaCl), potassium, magnesium, fiber, and caffeine.

Even with use of the Burke in-depth dietary interview to assess usual food, beverage, and nutrient intake during the preceding 28 days, correlation analysis (Pearson and Spearman) of the year 1 and year 2 data indicated that usual nutrient intakes were characterized with only moderate reliability. Thus, for macronutrients expressed as percent kilocalories (Table 1), simple product moment correlation coefficients were in the range 0.41 (mono- and polyunsaturates) to 0.54 (carbohydrates); for nutrients expressed as amounts per 1000 kcal or per day, from 0.52 (vitamin C/1000 kcal) to 0.64 (calcium mg/day); and for combined scores, from 0.38 (PFA/SFA) to 0.50 (Keys score). (In contrast, the correlation coefficient for weight measured at examination 1 and examination 2 was 0.96.) A consequence of this limited reproducibility was underestimation of strength of their relationships to BP change (regression dilution bias) and reduction in statistical power to detect true relationships.^{14,15,19,20,28–31}

Relationship of Baseline Individual Dietary Variables, Considered Separately, to Average Annual BP Change

Systolic BP Change

There were positive relationships of baseline intakes of total protein, animal protein, total fat, SFAs and monounsaturated fatty acids, cholesterol, Keys dietary lipid score, calcium, and heavy alcohol intake to average annual SBP change from baseline; postbaseline average annual change in weight was strongly related to SBP change (Table 2). There were inverse relationships of baseline vegetable protein, total carbohydrate, beta-carotene, and antioxidant index to average annual SBP change.

DBP Change

There were positive relationships of baseline total fat, saturates, monounsaturates, polyunsaturates, Keys score, and average annual weight change from baseline to average annual DBP change (Table 2). There were inverse relationships of baseline vegetable protein, vitamin C, beta-carotene, and antioxidant index to average annual DBP change.

TABLE 2. Relationship of Dietary and Other Variables to Average Annual Change in Blood Pressure, Each Dietary Variable Assessed Separately, GEE Analyses: Cohort of 1714 Men

Variable	Regression Coefficient (Z-Score)	
	SBP Change/Y, mm Hg	DBP Change/Y, mm Hg
Age, y	0.0394 (3.71)	-0.0048 (-0.79)
Education, y*	-0.0838 (-4.50)	-0.0299 (-2.67)
Height, m*	-0.0012 (-2.58)	-0.0002 (-0.69)
Weight, kg†	-0.0002 (-0.21)	-0.0024 (-3.97)
Body mass index, kg/m ² *	0.0016 (0.11)	-0.0346 (-3.88)
Cigarette smoking, (no, yes)*	0.2480 (2.64)	0.1163 (2.14)
Cigarettes/day*	0.0098 (2.45)	0.0023 (0.93)
Log cigarettes/day*	0.0884 (2.79)	0.0348 (1.87)
Alcohol: ≥2 drinks/day vs none or <2 drinks/day‡	0.3089 (2.21)	0.0561 (0.74)
Alcohol, mL/day‡	0.0031 (1.31)	0.0002 (0.12)
Log alcohol, log mL/day‡	0.0279 (0.74)	0.0033 (0.16)
Total energy, kcal/day§	-0.00007 (-1.01)	0.00003 (0.97)
Total protein, % kcal§	0.0461 (1.75)	-0.0147 (-0.98)
Animal protein, % kcal§	0.0567 (2.35)	-0.0022 (-0.16)
Vegetable protein, % kcal§	-0.2445 (-2.91)	-0.1353 (-2.80)
Total carbohydrate, % kcal§	-0.0189 (-1.75)	-0.0014 (-0.23)
Total fat, % kcal§	0.0250 (1.72)	0.0172 (1.92)
SFA, % kcal§	0.0594 (2.87)	0.0319 (2.74)
Monosaturated fatty acid, % kcal§	0.0334 (1.83)	0.0245 (2.32)
PFA, % kcal§	-0.0128 (-0.24)	0.0625 (2.02)
PFA/SFA, % kcal/% kcal§	-1.0625 (-0.18)	0.1626 (0.37)
Cholesterol, mg/1000 kcal§	0.0021 (2.73)	0.0002 (0.37)
Keys dietary lipid score ^x §	0.0208 (3.40)	0.0071 (2.00)
Vitamin C, mg/day¶	-0.0018 (-1.37)	-0.0011 (-1.69)
Vitamin C, mg/1000 kcal§	-0.0056 (-1.49)	-0.0048 (-2.24)
Beta-carotene, IU/day¶	-0.000035 (-1.92)	-0.000027 (-2.47)
Beta-carotene, IU/1000 kcal§	-0.000078 (-1.40)	-0.000093 (-2.82)
Antioxidant index, vitamin units/1000 kcal§	-0.0104 (-1.75)	-0.0116 (-3.33)
Calcium, mg/day¶	0.000246 (1.88)	0.000077 (1.10)
Calcium, mg/1000 kcal§	0.000591 (1.43)	0.000214 (0.93)
Change in weight, lb	0.2605 (12.66)	0.1785 (15.29)

Z-score is coefficient divided by standard error.

*Controlled for relationship of time, baseline age and variable of interest to average BP, and baseline age to average annual change in BP.

†Controlled for relationship of time, baseline age, height and weight to average BP, and baseline age and height to average annual change in BP.

‡Controlled for relationship of time, baseline age, education, height, cigarette use (no, yes), and variable of interest to average BP; baseline age, education, height, and cigarette use (no, yes) to average BP; baseline age, education, height, and cigarette use (no, yes) to average annual change in BP; baseline weight to average BP; and change in weight to change in BP.

§Controlled for relationship of time, baseline age, education, height, heavy alcohol use (≥2 drinks/day), and cigarette use (no, yes) and variable of interest to average BP; baseline age, education, height, heavy alcohol use (≥2 drinks/day), and cigarette use (no, yes) to average annual change in BP; baseline weight to average BP; and change in weight to change in BP.

¶Controlled for relationship of time, baseline age, education, height, heavy alcohol use (≥2 drinks/day), cigarette use (no, yes), total energy intake (kcal/day), and variable of interest to average BP; baseline age, education, height, heavy alcohol use (≥2 drinks/day), cigarette use (no, yes), and total energy intake (kcal/day) to average annual change in BP, baseline weight to average BP; and change in weight to change in BP.

||Controlled for relationship of time, baseline age, education, height, heavy alcohol use (≥2 drinks/day), cigarette use (no, yes), total energy intake (kcal/day), and weight to average BP; and baseline age, education, height, heavy alcohol use (≥2 drinks/day), cigarette use (no, yes), and total energy intake (kcal/day) to average annual change in BP.

TABLE 3. Relationship of Combinations of Dietary Variables to Average Annual Change in BP, GEE Analyses: 4 Multivariate Models, Cohort of 1714 Men

Variable	Regression Coefficient (Z-Score)							
	Systolic BP Change/Year, mm Hg				Diastolic BP Change/Year, mm Hg			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Alcohol ≥ 2 drinks/day vs none or < 2 drinks/day	0.4216 (2.64)	0.3788 (2.46)	0.3465 (2.50)	0.3736 (2.68)	0.0936 (1.05)	0.0637 (0.74)	0.0335 (0.44)	0.0408 (0.53)
Animal protein, % kcal	0.0411 (1.20)	0.0351 (1.01)	—	—	-0.0050 (-0.25)	-0.0063 (-0.31)	—	—
Vegetable protein, % kcal	-0.0861 (-0.83)	-0.0941 (-0.88)	-0.1748 (-2.01)	-0.1188 (-1.88)	-0.0889 (-1.48)	-0.1605 (-2.68)	-0.1119 (-2.29)	-0.0977 (-1.75)
Total carbohydrates, % kcal	0.0085 (0.55)	0.0035 (0.24)	—	—	0.0075 (0.83)	0.0042 (0.50)	—	—
SFA, % kcal	0.0211 (0.75)	—	—	—	0.0211 (1.37)	—	—	—
Dietary cholesterol, mg/1000 kcal	0.0015 (1.69)	0.0016 (1.91)	0.0018 (2.21)	—	0.0001 (0.11)	0.0001 (0.25)	0.0000 (0.02)	—
PFA/SFA ratio	—	-0.3347 (-0.39)	—	—	—	0.8914 (1.81)	—	—
Keys dietary lipid score	—	—	—	0.0151 (2.05)	—	—	—	0.0021 (0.49)
Antioxidant index	-0.0121 (-1.95)	-0.0127 (-2.05)	-0.0089 (-1.65)	-0.0083 (-1.41)	-0.0102 (-2.79)	-0.0104 (-2.83)	-0.0106 (-3.04)	-0.0105 (-3.02)
Calcium, mg/1000 kcal	0.0020 (0.33)	0.0003 (0.58)	—	—	0.0001 (0.37)	0.0002 (0.74)	—	—
Change in weight, kg*	0.1195 (12.86)	0.1196 (12.89)	0.1194 (12.86)	0.1193 (12.87)	0.0811 (15.42)	0.0810 (15.35)	0.0814 (15.45)	0.0815 (15.47)

Analyses controlled for relationship of time, baseline age, education, height, cigarette use (no, yes), weight, and baseline variables in the specific model to average BP; baseline age, education, height, and cigarette use (no, yes) to average annual change in BP; and baseline weight to average BP. Models 3 and 4 used only variables with larger Z-scores and coefficients for their relation to change in SBP and/or DBP (see Methods and Results sections).

*This coefficient measures the relation of change in weight to change in blood pressure.

Relationship of Multiple Dietary Variables, Considered Together, to Average Annual BP Change

Based on the foregoing findings, use was made of 4 GEE models incorporating multiple dietary variables to explore independent relationships of baseline dietary factors to change in BP. These models varied in dietary lipid variables (Table 3): model 1 included SFAs and cholesterol; model 2, PFA/SFA and cholesterol; model 3, cholesterol without SFA; and model 4, Keys score. They also assessed alcohol, animal and vegetable protein, total carbohydrate, antioxidant index, calcium, and change in weight, with control for age, education, height, and cigarette use (no, yes). Models 1 and 2 included 7 dietary variables; models 3 and 4 included 4 dietary variables.

SBP Change

There were independent positive relationships of heavy alcohol intake, cholesterol, Keys score, and weight change to average annual SBP change (Table 3). There were independent inverse relationships of vegetable protein and antioxidant index to SBP change.

DBP Change

There were independent positive relationships of PFA/SFA and of weight change to DBP change, and independent inverse relationships of vegetable protein and antioxidant index to DBP change (Table 3).

Signs for coefficients for the relationship of dietary calcium to BP change were all positive, not inverse; no coefficient or Z-score was of a size indicating a meaningful independent relationship (Table 3).

Discussion

These prospective data indicate the possible influence of several nutrients on BP change during 8 years for middle-aged men: for SBP, positive independent influences of dietary

cholesterol and Keys score (considered separately), and inverse influences of vegetable protein and of a combined antioxidant score (based on vitamins C and beta-carotene); for DBP, inverse influences of vegetable protein and antioxidant score. Also, these data are further evidence that gain in weight relates to rise in BP, as does habitual high alcohol intake.^{1,2,6,8-15,19,20}

These findings on specific nutrients and BP change need further research evaluation, for several reasons: first, virtually no other similar prospective data are available. The large Multiple Risk Factor Intervention Trial (MRFIT) cross-sectional study found a direct relationship of dietary cholesterol to BP,^{19,20} but virtually no other data—observational or interventional—are available on this matter. MRFIT also observed a positive association of Keys score to BP,^{19,20} but other cross-sectional studies—limited by small sample size and/or inexact methods of characterizing nutrient intake of individuals—have yielded inconsistent results on diet lipids and BP.

The observation here of an independent inverse relationship of vegetable protein to change in BP needs to be assessed further, especially because the WE study did not measure intake of salt, potassium, magnesium, or fiber. Foods supplying vegetable protein also are important sources of potassium, magnesium, and fiber; cross-sectional study findings indicate that these variables also relate inversely to BP.^{1,2,6,8-12,19-21} Therefore, vegetable protein in the WE analyses is possibly a marker for potassium, magnesium, and fiber and is not related independently to BP change. However, data from short-term randomized controlled trials indicate that increased vegetable protein from soybean has a BP-lowering effect.^{33,34}

WE data indicating an inverse relation of vegetable protein, but not animal or total protein, to BP change need also to be considered in relation to data from other studies.³⁵ Recently presented findings from the cross-sectional International Study on Macronutrients and Blood Pressure (INTERMAP)

Study also indicate an inverse relation of vegetable—but not animal or total—protein to BP.³⁶ On the other hand, reports from China and Japan suggest an inverse relation of animal protein to BP.^{37,38} International Study on Salt and Blood Pressure (INTERSALT) data, on >10 000 men and women from 52 diverse population samples worldwide, show significant independent inverse cross-sectional relationships of total protein to BP; 24-hour urinary total nitrogen and urea were used to measure total protein intake.^{10,21,22} Data from the MRFIT Study also indicate independent inverse cross-sectional relationships of total protein to BP; animal and vegetable protein were not reported.^{19,20}

The WE finding of an independent inverse relation to BP change of an antioxidant score based on vitamin C and beta-carotene is in a virtually uncharted research area.¹¹ Here, too, more work is needed.

The WE data on relation to BP change of dietary cholesterol, Keys dietary lipid score, beta-carotene, and vitamin C are concordant with the inference that modification in intake of these nutrients with the DASH combination diet contributed to its BP-reducing effect.^{17,18} The combination diet also entailed increased protein intake, from dairy and vegetable products. The DASH design, involving multiple modifications in food intake, precluded identifying effects of specific nutrient changes on BP.

In conclusion, exploratory prospective analyses—for the cohort of middle-aged employed men in the Chicago WE Study—indicate independent relationships to average annual change in BP of several specific nutrients assessed in-depth at baseline: dietary cholesterol and Keys dietary lipid score positively related to SBP change, vegetable protein and the antioxidant vitamin C and beta-carotene inversely related to BP change. They also confirm that baseline level of alcohol intake and weight gain during follow-up years is positively related to BP change. (The study had no data on dietary NaCl, potassium, magnesium, or fiber intake.)

BP and serum cholesterol have a comparable strong impact on coronary heart disease and cardiovascular disease risk. By the 1960s, extensive research demonstrated that several dietary factors independently influence serum cholesterol, ie, saturated fat, cholesterol, calorie balance directly, polyunsaturated fat, and water-soluble fiber inversely. These findings were the basis for population-wide recommendations to improve eating habits for prevention and control of adverse serum cholesterol levels. Their partial adoption has led to marked decline in average adult serum cholesterol level, from ≈235 to 240 mg/dL in the 1950s to 200 to 205 mg/dL in the 1990s.

In contrast, sustained research efforts to assess effects of multiple nutrients on BP date only from the 1980s. Since then, there have been significant advances, culminating in the findings of the DASH feeding trials. The DASH combination diet, improved in multiple ways from usual American fare, substantially lowers BP levels and is also effective in reducing serum cholesterol. The specific nutrients exerting BP-reducing effects—beyond lower intake of salt and avoidance of inadequate K intake, heavy drinking, and calorie imbalance—remain to be elucidated. Data here are relevant for this. More such are needed. Research along these lines should be

expanded, concurrent with ongoing efforts to improve population eating patterns for prevention-control of adverse BP and serum cholesterol levels. Major public health advances along these lines can contribute decisively to ending the coronary heart disease-cardiovascular disease epidemic in the next decades.

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