Dietary Calcium Lowers the Age-Related Rise in Blood Pressure in the United States: The NHANES III Survey

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This analysis of the third National Health and Nutrition Examination Survey (NHANES III) was designed to investigate the impact of dietary calcium intake on age-related changes in blood pressure and pulse pressure. Data on 17,030 participants 20 years or older (mean age, 48.8±0.2 years; 47% male, 42% Caucasian, and 28% African American) were used. Data included demographics, body mass index, blood pressure, and daily dietary calcium. Overall, average calcium intake was 761 mg/day. After adjusting for demographic and anthropomorphic variables, as well as total energy consumption, higher calcium intake was associated with lower rates of age-related increases of systolic blood pressure and pulse pressure (p<0.001). If the calcium intake of the general population were to increase to above 1200 mg, the incidence of isolated systolic hypertension in the elderly might be decreased. (J Clin Hypertens. 2003;5: 122–126) ©2003 Le Jacq Communications, Inc.

In industrialized societies, systolic blood pressure (SBP) increases with age, whereas diastolic blood pressure (DBP) decreases after the age of 50–60 years.[1–3] Consequently, pulse pressure (PP), which is the difference between SBP and DBP, increases steeply with age.[2,4] PP may be the most predictive blood pressure of cardiovascular morbidity and mortality.[5,6] In addition, these age-related changes of blood pressure explain the high prevalence of hypertension and the predominance of isolated systolic hypertension in the elderly population.[2,5,6] However, age-related changes of blood pressure are not universal and may be modified by diet. For example, societies that consume low-sodium diets do not demonstrate the age-related increase in SBP.[7,8]

Observational studies suggest an inverse association of blood pressure with dietary calcium, especially when calcium consumption is between 300–600 mg/day.[9] Meta-analyses of controlled clinical trials have shown that calcium supplementation (1000–2000 mg per day) results in a small but significant reduction in SBP only in hypertensive individuals.[10,11] This was not true for DBP.[10,11] In the Dietary Approaches to Stop Hypertension (DASH) trials,[12] a combination diet high in fruits and vegetables as well as low-fat dairy products had a significantly higher calcium content than the fruits-and-vegetable diet (534 mg/day vs. 1265 mg/day in the combination diet). Compared to the group on the fruits-and-vegetable diet, participants on the combination diet had a 2.7-mm Hg lower SBP (p=0.001) and a 1.9-mm Hg lower DBP (p=0.002). To our knowledge, no study has investigated the association between calcium and age-related changes in blood pressure.

We designed this analysis of the third National Health and Nutrition Examination Survey (NHANES III) to investigate the impact of dietary calcium intake on age-related changes in SBP, DBP, and PP.

METHODS

NHANES III is a stratified multistage probability sample of the US population.[13] Dietary information was obtained via a 24-hour recall questionnaire.

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Table I. Daily Calcium Intake by Gender and Ethnicity		
	NO. (%) OF SUBJECTS	CALCIUM DAILY INTAKE (MG/DAY)
Overall	17,030	761±4
Ethnicity*		
White	7121 (42%)	822±6
African American	4709 (28%)	637±7
Other	5200 (30%)	792±8
Gender*		
Males	7953 (47%)	867±7
Females	9077 (53%)	668±5
*p<0.0001		

Standardized blood pressure and anthropometric measurements were obtained by a trained observer. Of the 39,695 participants in NHANES III, we included participants 20 years of age or older (n=17,030) for this analysis. Our data set included demographic information (age, gender, and ethnicity), anthropometric information (weight, height, and body mass index (BMI) reported in the survey), and blood pressure (the mean of three readings of SBP and DBP). In addition to calcium intake, we included other dietary factors that potentially impact the age-related changes in blood pressure as covariates. These include sodium, potassium, magnesium, protein, alcohol, and total energy consumed per day in kilocalories. We excluded fats and carbohydrates due to lack of sufficient evidence to suggest an association. PP was calculated by subtracting the DBP from the SBP for each participant.

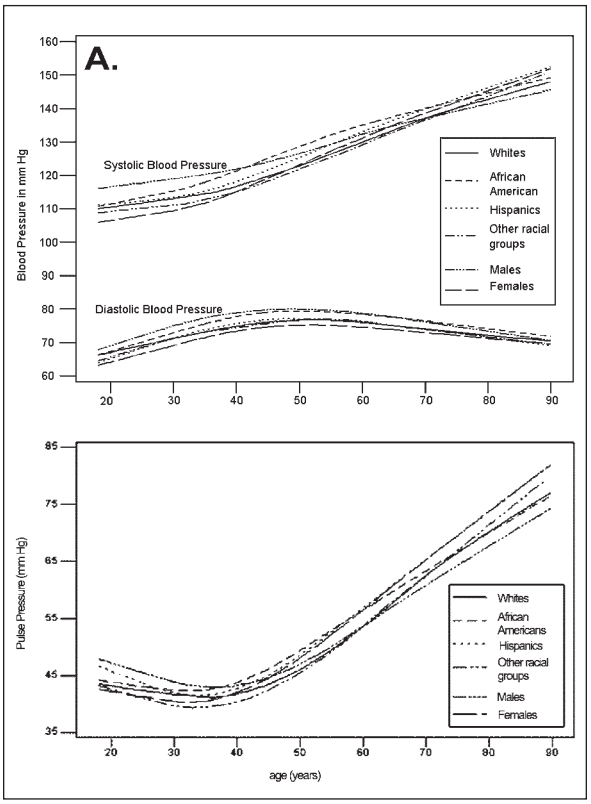

Figure 1. Blood pressure vs. age in all ethnic and gender groups

The outcome variables were the age-related changes in SBP, DBP, and PP. Univariate and multivariate analyses were performed to assess the impact of reported daily calcium consumption on the rate of change of blood pressure with age. In the multivariate analysis, adjustments were made for demographics, BMI, and the other dietary factors. To develop the multivariate model, a random subsample (n=8529) was selected from the total sample and used to select the best set of variables to be included in the final models. Standard stepwise regression[14] and best subset regression[15] were the statistical methods used for the selection of these variables. Principal component analysis was also performed.[14,15] The model was then tested on the remaining subsample (n=8501) using multiple-weighted regression to adjust for the stratified design. The model developed was applied to the overall sample (n=17,030). Calcium consumption was divided into three groups—low (<500 mg/day), moderate (500–1200 mg/day), and high (>1200 mg/day)—to simplify the analysis. Minitab Release 12.22 (Minitab, Inc., State College, PA, 1998) software was used for statistical analysis.

RESULTS

The sample satisfying our selection criteria included 17,030 participants. The mean age of the overall sample was 48.8±0.2 years, and 47% were males. Forty two percent were Caucasian, 28% were African

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Table II. Characteristics of the Three Calcium Intake Groups

	Calcium Intake Group (mg/day)		
	Low (<500)	Medium (500–1200)	High (>1200)
No. (%) of subjects	6078 (37%)	7904 (47%)	2707 (16%)
Age* (years)	48.8±0.3	46.5±0.2	41.9±0.4
Gender* (females)	62%	52%	37%
Ethnicity* (% C, AA, H, O)	34, 37, 24, 5	43, 25, 29, 3	47, 19, 30, 4
Body mass index* (kg/m^2)	27.4±0.08	26.9±0.06	26.4±0.1
Calcium intake* (mg/day)	320±1	788±2	1711±11
Energy consumption* (kcal/day)	1482±8	2166±9	3145±26
Calcium per energy* (mg/kcal)	0.24±0.002	0.41±0.002	0.61±0.005

C=Caucasian; AA=African American; H=Hispanic; O=other; *p<0.001 for comparison of three groups

American, 26% were Hispanic, and 4% were of other ethnic descent. The mean BMI of the sample was 27.1±0.2 kg/m^2. The mean BMI was highest for African Americans (Caucasians, 26.3±0.1 kg/m^2; African Americans, 27.7±0.1 kg/m^2; Hispanics, 27.4±0.1 kg/m^2; p value for comparison among three groups <0.001). There was no significant difference in total energy consumption between the ethnic and gender groups. The mean intake of calcium was 761±4 mg/day. Caucasians consumed the highest amount of dietary calcium per day whereas African Americans consumed the least (p<0.001) (Table I). Males consumed more calcium than females (p<0.001). Total daily energy and calcium consumption decreased with age. Participants younger than 65 years consumed a total of 2202±10 kcal/day and 783±5 mg/day of calcium, whereas participants 65 years or older consumed 1626±12 kcal/day and 694±7 mg/day of calcium (p<0.0001 for both).

After adjusting for gender, BMI, and ethnicity, SBP increased with age at a rate of 5.7 (SD, 0.6) mm Hg per each 10 years of age (p<0.001; R^2=40%) (Figure 1A). DBP increased at a rate of 3.4 (SD, 0.1) mm Hg per each 10 years of age (p<0.001; R^2=27%) until age 50 and then declined at a rate of 2.0 (SD, 0.1) mm Hg per each 10 years of age (p<0.001; R^2=11%). PP increased at a rate of 4.9 (SD, 0.05) mm Hg per each 10 years of age (p<0.001; R^2=32%) (Figure 1B). This pattern was true for all gender and ethnic groups.

A comparison of the three calcium intake groups is shown in Table II. Individuals that consumed the lowest amount of calcium (less than 500 mg per day) were older, more likely to be female and African American, and have a higher BMI compared to the other groups (p<0.001).

Calcium intake was inversely associated with the increase of SBP with age (Figure 2). After adjusting for gender, ethnicity, BMI, and total kilocalories, the rate of rise of SBP with age was lower as calcium consumption increased (p<0.001) (Table III). This remained true after adjusting for the intake of other dietary factors including sodium, potassium, magnesium, alcohol, and protein (p=0.02). The impact of calcium intake was similar on PP rise with age (Figure 3). Higher calcium intake was inversely associated with the increase of PP with age (Table III). Before age 50, calcium intake attenuated the rate of rise of DBP with age, but had a variable effect after age 50 (Table III). The impact of calcium on DBP and PP remained true after adjusting for gender, ethnicity, BMI, and total kilocalories, but was not significant after adjusting for other dietary factors' consumption.

DISCUSSION

This is the first study to investigate the impact of dietary calcium on the rate of change of blood pressure with age. As measured in the NHANES III

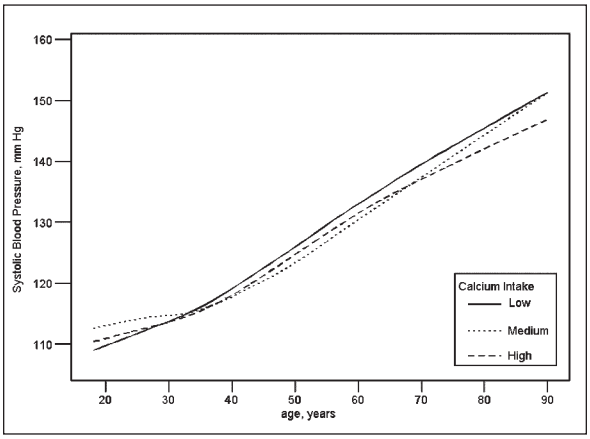

Figure 2. Systolic blood pressure vs. age in three calcium intake groups

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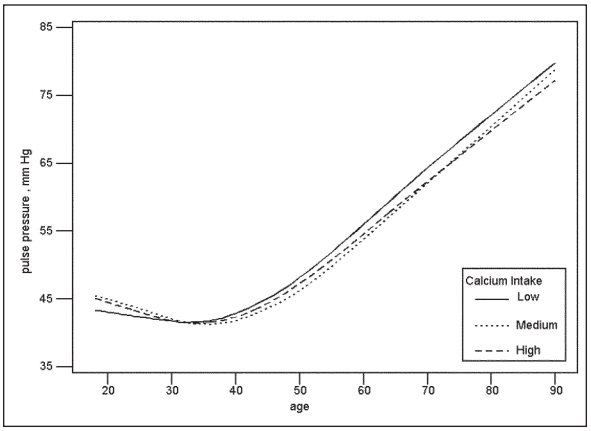

Figure 3. Pulse pressure vs. age in three calcium intake groups

survey, SBP increased at a rate of 0.57 mm Hg per year and PP increased at a rate of 0.49 mm Hg per year. This was true across all ethnic groups and in both genders. DBP increased until the age of 50 and then decreased. A higher intake of dietary calcium attenuated these age-related increases of both SBP and PP.

Observational studies have found conflicting results regarding the association between dietary calcium intake and blood pressure. Based on an analysis of the NHANES I, McCarron et al.[16] found that individuals with hypertension tend to have a lower calcium intake in their diets. However, subsequent analyses of NHANES I and II showed no association between blood pressure and calcium intake.[17] Based on an analysis of NHANES III data, we have previously found an inverse association of DBP with calcium intake and also inverse associations of both SBPs and DBPs with calcium intake after standardization for kilocalorie consumption.[4] However, in a multivariate analysis, after adjusting for consumption of other nutrients, we found no association between blood pressure and calcium intake. Two meta-analyses of observational studies[18,19] found different results concerning the association between blood pressure and calcium. In a prospective analysis of the NHANES I epidemiologic follow-up study,[20] calcium intake was associated with a lower incidence of hypertension in young but not in older participants. In the Nurse's Health Study,[21] calcium was associated with a protective effect on hypertension incidence in women. This observation was not confirmed in men in the Health Professional Follow-Up Study.[22] These apparently conflicting observations may reflect the difficulty of relating blood pressure levels to an independent effect of a single nutrient due to the high degree of multicollinearity of intake among nutrients. Nevertheless, in the present study, attenuation of the age-related increases of SBP and PP by calcium was apparent even after adjusting for consumption of other dietary factors.

The mechanism responsible for the rise of SBP and PP with age may be related to changes in the compliance of the vascular system,[2,23,24] although other mechanisms have been implicated (e.g., hormonal and autonomic changes).[25,26] We can only speculate about a possible mechanism by which calcium attenuates the age-related increases of blood pressure. In the Wistar-Kyoto rat, a high calcium intake affects vascular reactivity and subsequently lowers SBP with aging.[27] Similar findings were found in human trials where calcium supplementation was found to decrease vascular resistance and regression of left ventricular hypertrophy in black hypertensive diabetic men.[28]

SUMMARY

PP and SBP are important predictors of cardiovascular outcome in hypertensive patients.[5,6] Our finding that a higher calcium intake attenuates the

Table III. Rate of Change of Blood Pressure With Age in the Three Calcium Intake Groups

	Calcium Intake Group (mg/day)		
	Low (<500)	Medium (500–1200)	High (>1200)
Rate* of rise of SBP in mm Hg per 10 years of age† (SD)	6.5 (0.01)	5.8 (0.01)	5.1 (0.02)
Rate* of rise of PP in mm Hg per 10 years of age† (SD)	5.5 (0.09)	4.8 (0.08)	3.8 (0.01)
Rate* of change of DBP in mm Hg per 10 years of age† (SD)			
Before age 50	4.0 (0.1)	3.3 (0.1)	3.2 (0.2)
After age 50	–1.8 (0.1)	–2.3 (0.2)	–1.3 (0.3)

SBP=systolic blood pressure; DBP=diastolic blood pressure; PP=pulse pressure; *rate is adjusted for gender, ethnicity, body mass index, and total kilocaloric consumption per day; †p value for the rate of rise of blood pressure with age in the three groups: $p<0.001$

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age-related increments of PP and SBP has potentially important clinical implications. This observation suggests that increasing dietary calcium at the population level may decrease the incidence of hypertension and cardiovascular mortality from hypertension that has been linked to the higher PP and SBP in the population.

The advantages of this analysis are that this is a large community-based epidemiologic survey, which allowed us to perform multiple group and multivariate analyses. It also used PP and the rate of rise of blood pressure with age, both of which have not been frequently included in studies relating blood pressure to dietary intakes, especially calcium. The disadvantage of this survey is that it is a cross sectional study rather than a prospective survey. The cost and duration of a prospective epidemiologic study that investigates the impact of diet on the age-related changes in blood pressure is prohibitive.

In conclusion, based on the analysis of the NHANES III data, we found that higher calcium intake (>1200 mg/day) was inversely associated with the age-related increase in PP and SBP. If the calcium intake of the general population were to increase to this level, then the incidence of isolated systolic hypertension in the elderly might be decreased. Potentially, this would have a significant impact on decreasing hypertension related morbidity and mortality.

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