Dietary Calcium and Blood Pressure in National Health and Nutrition Examination Surveys I and II

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SUMMARY **It has recently been reported that a low intake of calcium may be a risk factor for hypertension. In view of the contradictory results, even when the same survey data base has been used by different researchers, an in-depth analysis was undertaken of the data provided by the two cycles of the National Health and Nutrition Examination Survey (NHANES). Both surveys, conducted in consecutive 4-year intervals during the 1970s, were designed to examine representative samples of the U.S. civilian noninstitutionalized population. The overall descriptive findings in relation to mean blood pressure and calcium intake were virtually identical in the two surveys. Based on "quantile" analysis, neither mean levels of blood pressure nor the prevalence of hypertension was related to calcium intake. Only among black men in NHANES I was a relationship between calcium intake and blood pressure noted. This finding was not apparent among black men in NHANES II or among any of the other sex-race groups in either survey. We conclude that the data of NHANES I and II do not show an association between low calcium intake and blood pressure. (Hypertension 8: 1067–1074, 1986)**

KEY WORDS • **calcium** • **blood pressure** • **diet** • **National Health and Nutrition Examination Survey**

INVESTIGATING the relationship between dietary factors and a chronic disease such as hypertension is difficult. Short-term dietary patterns, let alone lifetime habits, are hard to measure. Furthermore, hypertension develops over a period of many years, and cross-sectional studies may miss causal relationships altogether. On the other hand, it seems likely that dietary factors play a role in the development or prevention of hypertension in populations. Because of the urgency of our need to identify these dietary factors as a basis for primary prevention, we must use all potentially informative data sources on nutrient intakes and blood pressure. Nationally representative population samples offer unique advantages for these purposes, and the recurring U.S. surveys of the National Center for Health Statistics have become a crucial resource in this field.

Because of controversial reports of an association between low dietary calcium intake and high blood pressure based on data from the first National Health and Nutrition Examination Survey (NHANES I) and other studies,[1-7] we examined the entire data base provided by both the first and second NHANES. In addition to including data from both surveys, we incorporated the sampling weights and the complex survey design into the analysis. The weights are needed to adjust for differential sampling and nonresponse; they affect the estimated means and percentages. The clustered complex design affects variances and test statistics.[8]

Subjects and Methods

Both NHANES I and II were designed to be national probability samples of the civilian, noninstitutionalized U.S. population.[9-11] The first survey, NHANES I, took place during the years 1971 to 1974 and included 20,749 examined persons aged 1 to 74 years. The second study, NHANES II, was conducted during the years 1976 to 1980 and included 20,322 examined persons aged 6 months to 74 years.[12]

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Analytic Samples

The age range from the analytic samples from NHANES I and II that were used in this article was restricted to ages 40 to 74 years. Persons below 40 years were excluded from the analysis because hypertension occurs infrequently in younger persons. Persons 75 years and older were not included in the survey. Other exclusionary criteria used in the information of the analytic samples are listed in the Appendix (see p. 1071); the same exclusions were applied to both surveys. Additionally, one person in the NHANES II sample who reported consuming 8 quarts of milk and 9854 mg of calcium in one day was excluded from the final analytic sample.

Before any of the exclusions other than age were made, there were 7496 persons in the NHANES I study sample and 7380 persons in the NHANES II study sample. After the other exclusionary criteria were applied, the final analytic samples for NHANES I and II contained 5840 and 5490 persons, respectively.

The estimated civilian noninstitutionalized U.S. population represented by the number of examined persons when appropriately weighted closely approximates the U.S. population estimated by the U.S. Bureau of the Census at the midpoint of each survey.[12, 13]

Measurements

Dietary calcium intake was estimated in both surveys by using a single 24-hour recall.[9, 11] In the Nutrition Examination Sample of NHANES I, blood pressure was recorded once in the sitting position at the beginning of the medical examination by the physician. In NHANES II, the examining physician recorded each subject's blood pressure three times: 1) seated at the beginning of the examination, 2) recumbent at the end of the examination, and 3) seated at the end of the examination. So that the data from NHANES II would be comparable with NHANES I data, only the first seated blood pressure value from NHANES II was used in the analysis for this study. Systolic blood pressure (SBP) was taken as the first phase of Korotkoff sounds, and diastolic blood pressure (DBP) was taken as the fifth phase. The recommendations of the American Heart Association were followed for blood pressure measurement in both surveys. Body weight was measured on a carefully calibrated self-balancing scale. Height was measured using a device attached to the scale and recorded photographically.[14, 15]

Statistical Analyses

Two basic analytic strategies were used to investigate the possible association between dietary calcium intake and blood pressure. First, mean calcium intakes of normotensive (DBP < 90 mm Hg) and hypertensive subjects (DBP ≥ 90 mm Hg) were compared. Second, mean blood pressure (SBP and DBP) and prevalence of hypertension were calculated for persons within five dietary calcium intake groups. The five groups were composed of persons with calcium intakes of 1) 250 mg or less, 2) 251 to 500 mg, 3) 501 to 750 mg, 4) 751 to 1000 mg, and 5) more than 1000 mg. Mean blood pressure (SBP and DBP) and prevalence of hypertension in the first four calcium intake groups ($\leq$250–1000 mg) were compared with the values for the group with an intake of greater than 1000 mg. No comparison tests were made among the first four calcium intake groups.

Because of prior research supporting a negative association between dietary calcium and blood pressure, a one-sided t test was used to test the two primary hypotheses: 1) hypertensive subjects would have a significantly lower mean intake of dietary calcium than normotensive subjects and 2) subjects in the first four calcium intake groups would have significantly higher mean blood pressure and prevalence of hypertension than the subjects in the highest calcium intake group. For the multiple comparison tests of significance within the calcium intake groups, the critical value of the t distribution was based on the Bonferroni inequality.[16] The t value to achieve significance at a p level of 0.05 based on a one-sided test and four comparisons was 2.24. All analyses were conducted separately for each of the four race-sex groups, and within each race-sex group data were adjusted for age (in years) and body mass index (BMI). The BMI was defined as weight (kilograms) divided by height (meters) squared. Results were not affected by adjusting for potassium intake, education, poverty index,[12, 13] or, in NHANES II, serum zinc (data not shown).

All statistical analyses were conducted using the Statistical Analysis System (SAS)[17] and procedures developed at Research Triangle Institute and accessible through SAS.[18, 19] The complexities of the sample designs in NHANES I and II were incorporated in all analyses reported in this article. Thus, all reported statistics are estimates for the U.S. civilian, noninstitutionalized population. The rationale and importance of using sampling weights and design effects in the statistical analysis of NHANES data have been discussed elsewhere.[8] Unweighted sample sizes are also reported to provide an indication of the adequacy of the analytic sample sizes in the four subgroups.

Results

Except for the statistically significant drop in mean SBP and the increase in potassium intake from NHANES I to NHANES II, the analytic samples from the two surveys appear remarkably similar (Table 1). The means from one analytic sample to the next were generally very close to each other; the one exception was the NHANES I and II comparison for black men (Table 2). Black women had the lowest mean intakes of dietary calcium in both surveys, while mean intakes for black men were similar to the values for white women, and white men had the highest mean intakes (see Table 2).

Normotensive black men in NHANES I had a significantly ($p < 0.05$) higher mean intake of dietary calcium than did hypertensive black men after adjusting for age and BMI. In no other race-sex group in either analytic sample did normotensive subjects have sig-

TABLE 1. *Weighted Values for Selected Variables in Persons* Aged 40 to 74 Years from National Health and Nutrition Examination Surveys I and II*

Variable	NHANES I (n = 5840)	NHANES II (n = 5490)
Population estimate (thousands)	54,843	53,576
Age (yr)	54±0.2	54±0.3
Systolic blood pressure (mm Hg)	135±0.6	132±0.7†
Diastolic blood pressure (mm Hg)	84±0.4	83±0.5
Diastolic blood pressure ≥90 mm Hg (%)	33±1.3	34±1.7
Dietary calcium (mg)	702±12	699±13
Energy intake (kcal)	1834±24	1831±19
Dietary potassium (mg)	2267±31	2420±27†
Height (m)	1.67±0.002	1.68±0.002
Weight (kg)	72±0.24	73±0.24
Body mass index (kg/m^2)	25.7±0.1	25.8±0.1

Values are means ± SE. NHANES = National Health and Nutrition Examination Survey.
*Includes only black and white participants.
†$p < 0.05$, compared with NHANES I values.
Source: NHANES I (1971–1974), NHANES II (1976–1980). Hyattsville, MD: National Center for Health Statistics.

nificantly ($p<0.05$) higher mean intakes of dietary calcium after adjusting for age and BMI (see Table 2).

When hypertension was defined as a blood pressure of 160/95 mm Hg or greater, only the black hypertensive men from NHANES I were found to have a significantly ($p<0.05$) lower adjusted mean dietary calcium intake (514 ± 29 mg) than black normotensive men (738 ± 54 mg). When hypertension was defined as a SBP of 160 mm Hg or greater, hypertensive white women in NHANES I (604 ± 10 vs 553 ± 22 mg) and black hypertensive women in NHANES II (495 ± 29 vs 408 ± 59 mg) had significantly ($p<0.05$) lower adjusted mean calcium intakes than did white and black normotensive women, respectively. There were no other significant differences in either NHANES I or II. No significant differences were found when hypertension was defined as a DBP of 95 mm Hg or greater or as a blood pressure of 140/90 mm Hg or greater (data not shown).

Shown in Table 3 are the number of examined persons in each of the calcium intake groups by race and sex. For white men and women, there was a reasonably large number of examined persons in each group. However, the very small sample sizes for black men and women in the two highest calcium intake groups in both surveys and in the middle quintile group in NHANES II may lead to unreliable estimates of mean blood pressure. That fact must be taken into account when examining the results in Tables 4 and 5. The sample sizes for black men and women in the highest calcium intake groups were too small to estimate prevalence of hypertension; accordingly, only results for whites will be given when estimating the prevalence of hypertension (see Table 6).

Mean values for SBP and DBP after adjustment for age and BMI are shown by race and sex for each of the calcium intake groups in Tables 4 and 5. For black men, only mean SBP and DBP in the lowest calcium intake group (≤250 mg) and mean SBP in the 501 to 750 mg intake group were significantly ($p<0.05$) higher than the values for the highest calcium intake group (>1000 mg), and then only in NHANES I, not in NHANES II. There were no other statistically significant differences in either table, although black women in NHANES I showed a nonsignificant trend toward higher blood pressure with lower calcium in-

TABLE 2. *Comparison of Unadjusted and Adjusted* Mean Intake of Dietary Calcium Between Normotensive and Hypertensive Persons Aged 40 to 74 Years by Race and Sex from National Health and Nutrition Examination Surveys I and II*

Survey	Race	Sex	Normotensive† No. in analytic sample	Normotensive† Calcium intake (mg) Unadjusted	Normotensive† Calcium intake (mg) Adjusted	Hypertensive† No. in analytic sample	Hypertensive† Calcium intake (mg) Unadjusted	Hypertensive† Calcium intake (mg) Adjusted
NHANES I	Black	Men	215	722±52	725±51‡	208	580±69	577±67
		Women	246	435±36	432±38	227	389±27	393±29
	White	Men	1498	865±25	858±25	848	801±29	813±31
		Women	1866	601±10	590±10	732	586±20	615±20
NHANES II	Black	Men	135	598±49	605±53	122	621±61	613±53
		Women	126	482±42	480±41	116	474±54	476±50
	White	Men	1617	849±25	845±26	902	805±22	811±23
		Women	1786	606±16	598±15	686	570±15	591±16

Values are means ± SE. NHANES = National Health and Nutrition Examination Survey.
*Adjusted for age and body mass index.
†Normotensive = diastolic blood pressure <90 mm Hg; hypertensive = diastolic blood pressure ≥90 mm Hg.
‡$p < 0.05$, for comparison between adjusted means within a survey race-sex group.
Source: NHANES I (1971–1974), NHANES II (1976–1980). Hyattsville, MD: National Center for Health Statistics.

TABLE 3. *Number of Persons Aged 40 to 74 Years in Analytic Sample by Calcium Intake Group, Race, and Sex from National Health and Nutrition Examination Surveys I and II*

			Calcium intake (mg)				
Survey	Race	Sex	≤250	251–500	501–750	751–1000	>1000
NHANES I	Black	Men	111	127	82	50	53
		Women	149	165	93	35	31
	White	Men	194	570	528	400	654
		Women	443	819	629	337	370
NHANES II	Black	Men	62	77	42	37	39
		Women	85	81	33	24	19
	White	Men	179	618	603	420	699
		Women	442	807	592	307	324

NHANES = National Health and Nutrition Examination Survey.
Source: NHANES I (1971–1974), NHANES II (1976–1980). Hyattsville, MD: National Center for Health Statistics.

TABLE 4. *Adjusted* Mean Systolic Blood Pressure (mm Hg) by Calcium Intake Group, Race, and Sex for Persons Aged 40 to 74 Years from National Health and Nutrition Examination Surveys I and II*

			Calcium intake (mg)				
Survey	Race	Sex	≤250	251–500	501–750	751–1000	>1000
NHANES I	Black	Men	155†	141	146†	145	133
		Women	150	146	140	150‡	139‡
	White	Men	136	135	135	135	136
		Women	134	135	133	134	132
NHANES II	Black	Men	137	139	137‡	134‡	136‡
		Women	142	137	139‡	131‡	133‡
	White	Men	133	132	133	132	134
		Women	130	131	129	132	130

NHANES = National Health and Nutrition Examination Survey.
*Adjusted for age and body mass index.
†$p < 0.05$, $t_{0.05} = 2.241$. Within each race-sex group and survey, all comparisons were made against the highest calcium intake group (>1000 mg).
‡Due to small sample size, statistic may not be reliable.
Source: NHANES I (1971–1974), NHANES II (1976–1980). Hyattsville, MD: National Center for Health Statistics.

take. In NHANES I, however, there does appear to be a threshold effect at a calcium intake of 1000 mg in black men and women, but this may be due to the small sample size in the highest intake group. The possible threshold effect was not seen in whites from NHANES I or in any race-sex group in NHANES II. Notice also that, except for dietary calcium intake greater than 1000 mg, blacks of both sexes within the same calcium intake group tended to have higher mean SBP and DBP than their white counterparts.

The prevalence of a DBP of 90 mm Hg or more did not vary significantly ($p>0.05$) by calcium intake group for white men or women in either NHANES I and II (Table 6). Again, in neither NHANES I nor II was a significant difference found for either sex using any of the other four definitions of hypertension: 1) DBP of 95 mm Hg or more, 2) blood pressure of 140/90 mm Hg or more, 3) blood pressure of 160/95 mm Hg or more, and 4) SBP of 160 mm Hg or more (data not shown).

Discussion

The results of our analyses do not support the hypothesis that dietary calcium intake is negatively associated with blood pressure or the prevalence of hypertension, nor do they support the hypothesis that low calcium intakes by blacks can explain blood pressure differences between blacks and whites. Hypertensive subjects, defined as persons having a DBP of 90 mm Hg or more, did not report significantly lower dietary calcium intakes. Except for black men in NHANES I, mean blood pressure (SBP and DBP) in the lowest dietary calcium intake groups (≤250 mg) was not significantly greater than the means for the highest intake group (> 1000 mg), and the prevalence of hypertension in whites was not found to be related to intake of dietary calcium.

Our results do not rule out the possibility that such an association does exist, however. Two principal points need to be considered in this regard: 1) the design of NHANES I and II and 2) the effects of high

TABLE 5. *Adjusted* Mean Diastolic Blood Pressure (mm Hg) by Calcium Intake Group, Race, and Sex for Persons Aged 40 to 74 Years from National Health and Nutrition Examination Surveys I and II*

			Calcium intake (mg)				
Survey	Race	Sex	≤250	251–500	501–750	751–1000	>1000
NHANES I	Black	Men	98†	90	91	92	86
		Women	91	89	88	91‡	83‡
	White	Men	87	86	84	85	86
		Women	83	82	82	83	82
NHANES II	Black	Men	87	86	85‡	88‡	86‡
		Women	87	85	89‡	86‡	87‡
	White	Men	84	84	85	85	85
		Women	82	81	81	81	81

NHANES = National Health and Nutrition Examination Survey.
*Adjusted for age and body mass index.
†$p < 0.05$, $t_{0.05} = 2.241$. Within each race-sex group and survey, all comparisons were made against the highest calcium intake group (>1000 mg).
‡Due to small sample size, statistic may not be reliable.
Source: NHANES I (1971–1974), NHANES II (1976–1980). Hyattsville, MD: National Center for Health Statistics.

TABLE 6. *Adjusted* Prevalence of Hypertension (%)† by Calcium Intake Group, and Sex for Whites Aged 40 to 74 Years from National Health and Nutrition Examination Surveys I and II*

		Calcium intake (mg)‡				
Survey	Sex	≤250	251–500	501–750	751–1000	>1000
NHANES I	Men	41	44	31	36	36
	Women	26	26	27	27	27
NHANES II	Men	38	39	34	39	37
	Women	30	26	28	29	27

NHANES = National Health and Nutrition Examination Survey.
*Adjusted for age and body mass index.
†Hypertension was defined as a diastolic blood pressure ≥90 mm Hg.
‡$t_{0.05} = 2.241$. Within each sex group and survey, all comparisons were made against the highest calcium intake group (>1000 mg).
Source: NHANES I (1971–1974), NHANES II (1976–1980). Hyattsville, MD: National Center for Health Statistics.

APPENDIX. *Exclusions from National Health and Nutrition Examination Surveys I and II to Form Analytic Samples by National Center for Health Statistics Tape Catalog Number and Tape Positions*

	NHANES I		NHANES II	
Exclusions for	Tape catalog number	Tape positions	Tape catalog number	Tape positions
Age at interview	Any tape	101–102	Any tape	47–48
Race listed as other†	Any tape	103	Any tape	56
Missing systolic BP‡	4233	228–230	5305	791–793
Missing diastolic BP‡	4233	231–233	5305	794–796
Antihypertensive use§	4081	423	5020	1069
Oral contraceptive use	4081	464	5305	777
Pregnant at interview	4081	472	5305	785
Inputted 24-hour recall data	4701	481	5701	368

NHANES = National Health and Nutrition Examination Survey; BP = blood pressure.
*National Center for Health Statistics, Hyattsville, MD. NHANES I and NHANES II data release tapes are available from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161.
†Sample restricted to blacks (Race = 2) and whites (Race = 1). Persons with race listed as other (Race = 3) were excluded from the study sample because of small numbers.
‡For compatibility with the one measurement of blood pressure in NHANES I, only the first seated blood pressure from NHANES II was used in the analyses.
§Regular (1) or occasional use (2) at time of interview in NHANES I; use (1) at time of interview in NHANES II (Numerals 1, 2, and 3 represent coding on tapes).

ratios of within-person (σ_w^2) to between-person (σ_b^2) variation in the intake of dietary calcium and in SBP and DBP.

Both NHANES I and NHANES II were cross-sectional surveys. As a result, a person's reported dietary calcium intake may not accurately represent the usual intake over a long period before the survey or, for that matter, the usual intake at present.[20, 21] An epidemiological follow-up survey of adults examined in NHANES I has recently been completed, and future analysis of those data will be helpful in investigating the relationship of prior dietary calcium intake to blood pressure and the incidence of hypertension.[22]

Reported dietary intake was estimated in both surveys from one 24-hour recall. The estimated intakes, as such, do not include nutrient intake from nonfood sources (e.g., vitamin or mineral supplements) or water. Calcium supplement use does not appear to have been common at the time of either survey. Of approximately 20,000 persons examined in each survey, only 26 people in NHANES I and 65 in NHANES II stated that their primary supplement was a calcium supplement. However, the more common usage of multivitamin or mineral supplements would have supplied some calcium that would not be accounted for in the intake estimates for dietary calcium. Although water hardness data are available from an augmentation survey to NHANES I, there are no such data for the general sample from NHANES I or NHANES II. Water accounts for a significant proportion of total calcium intake.[23] However, a recent study that accounted for calcium intake from all sources also failed to find a significant relationship between estimated current calcium intake and blood pressure.[24]

A phenomenon that also plays an important role in the ability to estimate accurately an individual's usual intake of calcium, or an individual's usual value for any variable (e.g., blood pressure), is the ratio of the amount of variation within (σ_w^2) to the amount of variation that exists between (σ_b^2) individuals. High ratios of σ_w^2/σ_b^2 will bias correlation and slope coefficients toward zero.[20, 21] In general, ratios of σ_w^2/σ_b^2 for dietary intake are greater than 1, indicating that there is more variation within the diets of individuals than there is between them.[20] In cross-sectional surveys such as NHANES I and II, in which subject's intake is estimated from only one 24-hour recall or diet record, this implies that correlation and slope coefficients based on individual data will underestimate the magnitude of the association under investigation.[20, 21, 25–30] The ratio of σ_w^2/σ_b^2 for calcium has been estimated to be approximately equal to 1.[20, 28] As a result, the observed regression slope for the model in which blood pressure is regressed on each subject's dietary calcium intake may underestimate the true slope by 50% or more.[20]

There are only two ways to reduce the impact of high ratios of σ_w^2/σ_b^2: 1) increase the number of measurements of diet or blood pressure to be collected from each person, which in the case of a completed survey like the NHANES is a moot point, and 2) base the analysis on groups instead of individuals.

Although there is within-person variability associated with blood pressure, the ratios of σ_w^2/σ_b^2 for SBP (0.22) and DBP (0.26) were small (ratios of σ_w^2/σ_w^2 for SBP and DBP were estimated from NHANES II data by applying the correlation between the first and second seated SBP [$r_{12} = 0.821$] and DBP [$r_{12} = 0.792$] to the formula $\sigma_w^2/\sigma_b^2 = [1 - r_{12}]/r_{12}$ from Liu et al.[21]) As a result, our major concern was for the ratio of σ_w^2/σ_b^2 for dietary calcium. By breaking up dietary calcium intake into quintiles, we were able to reduce misclassification error. For example, given σ_w equal to 255 for calcium,[29] and one 24-hour recall, the probability (p) of misclassifying a subject from the fifth quintile (> 1000 mg) to the first, second, or third quintiles was 0.0013, 0.023, and 0.159, respectively. As a result, misclassification error should not have affected our comparisons of SBP and DBP between the first and fifth quintiles and the second and fifth quintiles.

Even in using a "quantile" method of analysis, potential problems remain. First of all, as shown, there must be a sufficiently large distance between the two groups being compared to gain any advantage at all. Second, the accuracy of the estimate of the mean value for the group and the power to detect differences between groups are also a function of the sample size. The requirements of large numbers of groups and a large sample size within each group tend to oppose each other. For a fixed sample size, therefore, only a limited number of groups is possible.

Sample size and power are also important issues when comparing means between normotensive and hypertensive subjects. For black men and women, the power to detect a 100-mg difference in mean dietary calcium intake varied from approximately 0.9 in NHANES I to 0.7 in NHANES II. (The power estimates were calculated assuming the following for blacks: at least 200 people per group in NHANES I and 125 people per group in NHANES II; and for white: at least 700 people per group in either survey; value of $\sigma_w = 255$ for calcium; one 24-hour recall, and $\alpha = 0.05$ (one-sided) equal to 1.645.[16, 21, 29]) The lower power in NHANES II reflects the smaller analytic samples for black men and women in that survey (see Table 2). The small sample also may have contributed to the inability to find an association between calcium and blood pressure for black men and women in NHANES II. For white men and women, the sample sizes shown in Table 2 were large enough to detect a 50-mg difference in mean dietary calcium intake with a power of approximately 0.8.

Another factor that could have affected our ability to find an association between dietary calcium and blood pressure was the exclusion of all persons receiving antihypertensive medication. People receiving antihypertensive medications may represent a pool of calcium-sensitive individuals. It was necessary, however, to exclude these persons from analysis, since their blood pressure values while receiving medication would not represent their "real" value. From NHANES I to NHANES II there was approximately a 10% increase in the number of people receiving antihypertensive medication. Their exclusion from both analytic samples coupled with their increase in NHANES II may have biased the results from NHANES I, and especially those from NHANES II, toward finding no association.

The use of "quantile" methods of analysis for these cross-sectional data provided results that seem to contradict results found by other investigators using NHANES I and II data, who reported finding a statistically significant association between dietary calcium intake and blood pressure.[1, 7, 31] Careful comparison of the reported findings, however, resolves this apparent contradiction. The article by McCarron et al.[7] has been reviewed elsewhere[32] and need not be discussed here. Recently, Harlan et al.[1, 31] have published two additional articles on blood pressure–nutrient associations, based on subsamples from NHANES I and II. In both reports stepwise regression procedures were used to determine the best predictors of blood pressure from a group of approximately 30 variables, which included dietary calcium intake. The NHANES I data were reported by sex and by race but, because of the small sample size, were not cross-classified into the four sex-race groups used for this analysis. Similarly, NHANES II data were reported by sex alone.

Based on data from the NHANES I sample of persons aged 25 to 74 years who received a detailed medical examination, it was reported that low dietary calcium was a predictor of SBP in men, DBP in women, and DBP in blacks.[1] However, the coefficient for SBP for men was positive, and for women was nonsignificant ($t = -1.89$). Thus, only for DBP among blacks was the association between calcium and DBP both significant and negative. Based on data from a different subsample from NHANES II, dietary calcium was not associated with blood pressure in men or women, although the authors did report a significant association between the scaled frequency of consumption of calcium-rich foods and blood pressure in women alone.[31] Finally, a recent reanalysis of NHANES I data demonstrated an association only among black men.[33] What emerges from these various methods of analysis, in our view, is that there was a negative association between dietary calcium and blood pressure only in black men and only in NHANES I. Given the multiple subgroups examined, and the lack of confirmation of this finding in NHANES II, it would seem reasonable to regard this as a chance finding that has yet to be confirmed by replication.

Four additional epidemiological surveys have examined the relationship between dietary calcium and blood pressure. A low intake of milk products or calcium was associated with higher blood pressure in studies from Honolulu, Puerto Rico, and San Diego.[2–4] Persons with cardiovascular disease who participated in those cardiovascular disease surveys may have reduced their fat intake, however, thus confounding the milk–blood pressure association. Nichaman et al.[5] reported an association between calcium intake and DBP in multiple linear regression analysis performed on the baseline data in the Western Electric Study. An additional case-control study suggested that hypertensive subjects consumed less calcium.[6] Only 45 participants were included in each group in this last study, however, and while patients were drawn from a clinic population, controls were apparently university personnel. All of the dietary differences in calcium could be explained by increased yogurt and cheese consumption in the controls. Dietary supplementation with calcium has also been reported to reduce blood pressure in normotensive volunteers in one study[34] and in persons receiving antihypertensive medication in another study.[35]

In contrast to the contradictory findings for dietary calcium and blood pressure, a highly consistent relationship between total serum calcium and blood pressure appears to be established. Several large studies, most including more than 10,000 participants, have demonstrated a significant increase in blood pressure with rising levels of total serum calcium.[1, 36–39] McCarron,[40] on the other hand, has reported lower ionized calcium in a series of 23 patients, while two additional studies found no difference between patients and controls in ionized calcium.[41, 42] A high correlation between ionized and total serum calcium exists in persons with normal serum albumin; thus, opposite associations with hypertension seem unlikely. The weight of the evidence therefore supports a positive association between serum calcium and blood pressure. Whether dietary factors play a significant role in this association, or whether higher serum calcium is a result of hypertension itself, remains to be determined. Investigations into the physiological controls of ionized calcium, as well as magnesium and vasoactive hormones, may further elucidate these matters.[43] There is, however, some suggestion that hypertensive subjects with low serum levels of ionized calcium and low plasma renin levels may respond to calcium supplementation.[44] Our results do not rule out the possibility that there may be a subgroup of hypertensive subjects for which a negative relationship exists between blood pressure and calcium intake.

A new and interesting field of investigation has been developing in relation to cellular calcium and hypertension. High free cytosolic calcium in platelets[45, 46] has been reported in hypertensive subjects, along with a variety of abnormalities in flux rates and binding of calcium.[47, 48] These findings are yet too fragmentary to allow definitive conclusions, however. It seems likely, nonetheless, that the relationships among dietary, serum, and cellular calcium are complicated and indirect, with a number of independent control mechanisms involved in the regulation of serum and intracellular levels. Although the available evidence supports the view that calcium is higher in the serum and cells in hypertensive subjects, the importance of dietary calcium, in our opinion, remains controversial.

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