Dairy products, calcium, and blood pressure[1–3]

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ABSTRACT The previously reported inverse association of dietary calcium intake and blood pressure levels was examined in a Southern California community, in order to determine whether this association was independent of age, obesity, and alcohol consumption. In the total population significantly less calcium intake from milk was reported in hypertensive versus normotensive men (but not women) and the association was independent of age and obesity. In a 23% subsample of men from this cohort the effect of total dietary calcium intake from all dairy products was estimated from a 24-h dietary recall. Again hypertensive men consumed significantly less calcium than normotensives. In men, both systolic and diastolic blood pressure levels were inversely associated with calcium intake from dairy products. After controlling for age, obesity, and alcohol, diastolic blood pressure was negatively and significantly associated with total calcium intake from dairy products, while systolic blood pressure was similarly associated with whole milk calcium alone. Although these data are cross-sectional, they suggest that some component of dairy products, probably calcium, exerts a protective effect against hypertension, and are compatible with the protective effect of calcium reported in hypertension-prone rats. *Am J Clin Nutr* 1983;38:457–461.

KEY WORDS Blood pressure, calcium, dairy products, population studies

Introduction

Three studies to date have reported an inverse association between dietary calcium intake and blood pressure levels. In a community study of 100 black women with mean age 20, Langford and Watson (1) found that women with systolic blood pressures less than 105 mm Hg consumed more calcium than did those with systolic blood pressures greater than 125 mm of Hg. Using data based on 4944 individuals age 35 to 75 yr from the HANES 1 survey, McCarron and Morris (2) reported a significantly lower intake of calcium among untreated hypertensives (>160/95) compared to those with borderline (140 to 160/90–95) or normal blood pressure (<140/90). In a third study, 46 untreated hypertensives (>95 mm Hg diastolic or >105 mm Hg mean arterial pressure) with a mean age 42 yr, diagnosed at a hypertension clinic, consumed significantly less calcium compared to 44 normotensive healthy volunteers with a mean age 39 yr (3). These important observations suggesting that a common nutrient might be inversely related to blood pressure were nevertheless flawed, in that no adjustment was made for differences in age. In Westernized cultures calcium intake falls with age (4), whereas blood pressure rises (5).

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We report herein the relationship of dairy products and calcium intake to systolic and diastolic blood pressure levels in an adult, predominantly white, upper middle-class community. The possibility that confounding factors of age, obesity, and alcohol explain the relationships is also examined.

Methods

Between 1972 and 1974, 82% of all adult residents of Rancho Bernardo, a geographically defined, predominantly white, upper middle-class Southern California community participated in a survey for heart disease risk factors as part of a Lipid Research Clinic prevalence study, known as visit 1. Interviewers used standardized forms to obtain information on age, use of hypertensive medication, and daily consumption of whole milk. Milk consumption was assessed as one of two nutrition questions (the other related to egg consumption), designed to test awareness of the relationship between dietary fat intake and heart disease; subjects were asked "How many cups of whole milk do you drink each day?" Height and weight were measured in light clothing without shoes. Obesity was determined by body mass index (weight/height^2). Blood pressure was measured using a standard sphygmomanometer after the subject had been seated for at least 5 min. Subjects with a systolic blood pressure greater than 160 mm Hg and/or a diastolic blood pressure greater than 90 mm Hg had a second blood pressure measurement, and the lower of the two readings was recorded.

A 15% random sample of this population as well as all persons with elevated lipid levels or who were on lipid-altering medication were invited for a second, more extensive evaluation. At visit 2, height, weight, blood pressure, and obesity were determined by the same protocol used at visit 1. Current antihypertensive and diuretic drug use was determined by interview, and confirmed by examination of medication or prescriptions brought to the clinic for this purpose. A certified Lipid Research Clinic dietitian obtained a 24-h dietary recall of all nutrient and alcohol intake, using food models and containers to assess quantity. Consumption of dairy products, including whole milk, low- and nonfat milk, cream, cheese, and frozen dairy products, was converted into milligrams of calcium intake, using the USDA Agricultural Handbook no 456 (6) by one of us (SA) who was blind to the blood pressure of the subjects.

Analysis of whole milk and blood pressure data collected at visit 1 was done separately for men and women aged 30 to 79 yr. Visit 2 analysis of dairy products and calcium intake was restricted to men between the ages of 30 and 79 yr, combining random sample and hyperlipidemic subgroups who showed no significant differences in systolic or diastolic blood pressures or dietary calcium. For visit 1 and visit 2 analyses, individuals were grouped into four blood pressure categories, normotensives (<140 and <90), borderline hypertensives (≥140 and <160, ≥90 and <95), hypertensives (≥160 or ≥95), and treated hypertensives. Visit 1 treated hypertensives include all individuals reporting use of antihypertensive medication. Visit 2 treated hypertensives include individuals reporting antihypertensive medications and/or diuretics. Differences in unadjusted mean calcium intake from whole milk, other milk, total milk, nonliquid dairy products, and all dairy products between each hypertensive group and normotensives were tested using *t* tests. Differences in unadjusted, age- and obesity-adjusted mean blood pressure levels among four categories of whole milk consumption were tested using analysis of variance and

TABLE 1
Whole milk consumption (cups per day) among normotensive, borderline, treated, and untreated hypertensive men and women aged 30 to 79 at visit 1

	30–54 years			55–79 years			All		
	Mean	SD	n	Mean	SD	n	Mean	SD	n
Men									
Normotensives	0.97	1.47	598	0.72	1.18	550	0.85	1.34	1148
Borderline hypertensives	0.88	1.39	89	0.67	0.94	398	0.71*	1.04	487
Untreated hypertensives	0.54*	0.80	48	0.64	1.10	321	0.63*	1.07	369
Treated hypertensives	0.46*	0.90	37	0.42*	0.77	285	0.43*	0.79	322
Women									
Normotensives	0.50	0.97	775	0.38	0.75	772	0.44	0.87	1547
Borderline hypertensives	0.55	1.13	87	0.45	0.86	408	0.46	0.91	495
Untreated hypertensives	0.64	1.02	36	0.48	0.78	290	0.50	0.81	326
Treated hypertensives	0.42	0.95	38	0.32	0.68	318	0.33*	0.71	356

* Significantly lower than normotensives at $p < 0.05$.

TABLE 2
Systolic and diastolic blood pressure levels among men and women aged 30 to 79 at visit 1 by consumption of whole milk (cups/day) adjusted for age and obesity

	Systolic				Diastolic				
	Unadjusted mean	SD	Adjusted for age	Adjusted for age and obesity	Unadjusted mean	SD	Adjusted for age	Adjusted for age and obesity	n
Men									
Whole milk cups/day									
0	138.0	22.9	137.5	137.2	81.8	11.5	81.7	81.5	1330
1	137.8	23.3	137.4	137.5	81.4	11.5	81.3	81.4	613
2	135.6	22.1	136.5	137.1	80.4	10.5	80.5	81.0	233
3+	129.1	20.8	134.0	134.4	77.2	9.6	78.1	78.4	150
Significance level	$p < 0.05$		NS	NS	$p < 0.05$		$p < 0.05$	$p < 0.05$	
Women									
0	131.6	23.7	131.4	131.3	78.8	11.3	78.8	78.7	1935
1	132.2	23.5	132.0	132.2	79.4	11.6	79.4	78.4	532
2	133.1	21.7	133.2	133.7	80.0	10.7	80.0	80.3	164
3+	129.5	24.1	132.7	133.6	77.9	11.5	78.7	79.2	93
Significance level	NS		NS	NS	NS		NS	NS	

covariance, respectively. In addition, correlation coefficients were calculated between systolic and diastolic blood pressures and calcium intake, with partial correlation coefficients computed to control for differences in age, obesity, and alcohol intake. Because previous findings of an inverse relationship between dietary calcium intake and blood pressure levels were being tested, statistical significance was assessed using one-tailed tests with p values of 0.05.

Results

Table 1 shows mean whole milk intake by blood pressure group for both sexes and two age categories, 30 to 54 and 55 to 79, using visit 1 data for 5050 men and women. Reported whole milk consumption was significantly lower in the older versus younger subjects, and was lower in women than in men. In men, whole milk consumption was also significantly lower in borderline, untreated and treated hypertensives compared to normotensives. In women, whole milk consumption was significantly lower only in treated hypertensives compared to normotensives. **Table 2** displays age- and obesity-adjusted mean systolic and diastolic blood pressure levels among all visit 1 subjects for four categories of whole milk consumption. In men, both systolic and diastolic blood pressures decrease with increasing calcium intake, but only changes in diastolic blood pressures showed a significant ($p < 0.05$) trend after adjusting for age and obesity. A significant trend was not seen in women.

Further analyses were confined to visit 2 men. There were no significant differences in age, blood pressures, dairy product use, or calcium intake between the hyperlipidemic and random sample men (not shown). Therefore these groups were combined to provide a sufficient number of normotensives (247), borderline hypertensives (132), untreated hypertensives (63), and treated hypertensives (99) for analysis. As seen in **Table 3**, both treated and untreated hypertensives consumed more alcohol and had a lower total calorie intake than normotensives, but only the latter difference was statistically significant. Whole milk calcium was significantly and negatively correlated with alcohol intake ($r = -0.115$; $p = 0.002$) after controlling for age and obesity. Untreated hypertensive men had a significantly lower intake of whole milk calcium, total milk calcium (whole, nonfat, and low-fat milk), other milk calcium, and calcium from all dairy products combined than normotensives ($p < 0.05$).

Table 4 summarizes partial correlation coefficients adjusted for age, obesity, and alcohol intake based on data from all 541 visit 2 men. After adjustment, calcium from all dairy products was significantly and inversely correlated to diastolic blood pressure ($r = -0.067$; $p < 0.05$). Systolic blood pressure was negatively and significantly correlated with whole milk calcium after adjust-

TABLE 3
Daily intake of dairy product calcium, alcohol and total calories among normotensive, borderline, treated, and untreated hypertensive visit 2 men aged 30 to 79

	Normotensives		Borderline hypertensives		Untreated hypertensives		Treated hypertensives	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total calcium (mg/day)	425.2	391.1	493.5	463.4	297.9*	311.0	351.7	372.2
Whole milk calcium (mg/day)	130.5	257.5	140.5	288.5	72.2*	162.8	85.6*	172.3
Other milk calcium (mg/day)	155.5	271.2	192.5	357.1	102.4*	199.0	183.2	338.3
Total milk calcium (mg/day)	286.0	331.0	332.9	410.1	174.6*	236.2	268.9	348.5
Nonliquid dairy products calcium (mg/day)	139.2	204.5	160.6	213.6	123.4	174.8	82.8*	119.8
Alcohol (g/day)	22.2	28.3	22.1	29.0	26.5	31.1	27.0	28.6
Calories	2256.3	732.9	2285.3	749.2	2044.2*	471.7	2042.2*	672.1
n	247		132		63		99	

* Significantly lower than normotensives at $p < 0.05$.

TABLE 4
Partial correlation coefficients of total calcium and whole milk calcium intake with systolic and diastolic blood pressure levels among visit 2 men aged 30 to 79

	Systolic (n = 541)	Diastolic (n = 541)
Total calcium intake (mg/day)		
Unadjusted	−0.073*	−0.079*
Adjusted for age	−0.035	−0.074*
Adjusted for age, obesity	−0.031	−0.070*
Adjusted for age, obesity, alcohol	−0.028	−0.067*
Whole milk calcium intake (mg/day)		
Unadjusted	−0.090*	−0.052
Adjusted for age	−0.075*	−0.049
Adjusted for age, obesity	−0.072*	−0.046
Adjusted for age, obesity, alcohol	−0.067*	−0.040

* Significantly less than zero at $p < 0.05$.

ment for age, obesity and alcohol intake ($r = -0.067$; $p < 0.05$).

Discussion

In this defined population, both a crude estimate of daily milk consumption and a dietitian-quantitated 24-h diet recall showed a significant association of low calcium intake from dairy products with elevated blood pressure in men. This association is not strong, a finding that is not surprising given the high daily variability of both dietary intake and blood pressure, but the results are consistent with those reported previously (1–3). Further, the inverse association of calcium intake and blood pressure is independent of age and obesity, although blood pressure tends to increase with age and obesity (5), while milk consumption decreases with age (4). The association is also independent of alcohol consumption, despite the finding that milk and alcohol intakes were inversely related in this cohort, and the fact that alcohol consumption has been shown elsewhere to be linearly associated with blood pressure in men (7). The observation that calcium intake was more strongly correlated with diastolic than systolic blood pressure may reflect either the greater variability of systolic blood pressure, or the stronger association of systolic blood pressure with age, obesity, and alcohol use. The failure to find the same association in women could reflect a true lack of association or, more probably, the poorly understood but clearly more complex relationship of covariates to blood pressure in women; unlike men, women show a nonlinear relationship of alcohol to blood pressure (7).

We were unable to calculate calcium from nondairy products in this study, but dairy products account for nearly 80% of total calcium intake in the American diet (8). The mean intake of calcium at visit 2 from all dairy products was only 414 mg, considerably below the Recommended Daily Allow-

ance of 800 mg (9), possibly reflecting the avoidance of dairy products in a heart-disease concerned older cohort, 20% of whom reported being on a "special diet." The mean calcium intake from whole milk reported for visit 1 men was 210 mg, significantly greater than the mean 118 mg calcium intake from whole milk reported at visit 2. Although the visit 1 question was designed to exclude low-fat and nonfat milk, it appears that visit 1 participants reported not just whole milk but all types. Although McCarron et al (3) suggested that differences in calcium intake between hypertensives and normotensives were mainly from nonliquid dairy products, in this population differences in calcium intake among blood pressure groups were most strongly related to differences in milk consumption.

In the present analysis we were unable to determine whether calcium from nondairy sources was a significant component of the diet of this cohort, or whether nondairy calcium is also inversely associated with blood pressure. It is possible that some component of dairy products other than calcium affects blood pressure levels. At present, however, calcium seems the most likely factor, based on the demonstrated protective effect of calcium supplements in the hypertension-prone rat (10, 11), the reduced levels of serum ionized calcium found in hypertensive animals (12, 13) and man (14), the effect of increasing levels of ionized calcium on smooth muscle relaxation (15, 16), and the recent clinical trial showing blood pressure reduction after calcium supplements (17). It is also interesting to note that the most commonly used antihypertensive agents, the thiazide diuretics, increase serum ionized calcium and induce a positive calcium balance (18).

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