Milk, Dietary Calcium, and Bone Fractures in Women: A 12-Year Prospective Study

ABSTRACT

Objectives. This study examined whether higher intakes of milk and other calcium-rich foods during adult years can reduce the risk of osteoporotic fractures.

Methods. This was a 12-year prospective study among 77 761 women, aged 34 through 59 years in 1980, who had never used calcium supplements. Dietary intake was assessed with a food-frequency questionnaire in 1980, 1984, and 1986. Fractures of the proximal femur (n = 133) and distal radius (n = 1046) from low or moderate trauma were self-reported on biennial questionnaires.

Results. We found no evidence that higher intakes of milk or calcium from food sources reduce fracture incidence. Women who drank two or more glasses of milk per day had relative risks of 1.45 for hip fracture (95% confidence interval [CI] = 0.87, 2.43) and 1.05 for forearm fracture (95% CI = 0.88, 1.25) when compared with women consuming one glass or less per week. Likewise, higher intakes of total dietary calcium or calcium from dairy foods were not associated with decreased risk of hip or forearm fracture.

Conclusions. These data do not support the hypothesis that higher consumption of milk or other food sources of calcium by adult women protects against hip or forearm fractures. (*Am J Public Health.* 1997;87: 992–997)

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Introduction

Numerous clinical investigations have demonstrated that calcium supplementation can retard bone loss among adult women.[1–7] However, inconsistent results from prospective studies and interventions trials[8–14] have not provided strong support for a positive association between adult calcium intake and osteoporotic fractures. Though bone fragility may be largely explained by low bone mass,[15,16] direct investigation of the effects of diet on bone fractures is warranted because characteristics of bone other than mass, such as microscopic fatigue damage and the loss of connectivity in supporting trabeculae,[17] contribute to fracture risk. Furthermore, foods high in calcium may contain other factors that influence fracture risk.

The present study expands upon previous work by observing a large cohort of women for 12 years with repeated measures of dietary intake and ongoing reporting and characterization of bone fractures by level of trauma. We focused our investigation on milk and dietary sources of calcium, rather than the use of calcium supplements, in order to examine the validity of public health messages and advertisements that advise women to increase their milk consumption for the prevention of osteoporosis.

Methods

The Nurses' Health Study includes 121 701 female registered nurses in 11 states who were 30 to 55 years of age when they returned an initial questionnaire in 1976. Approximately 98% of the cohort is White. Follow-up questionnaires have been mailed every 2 years to update information on medical conditions, weight, postmenopausal estrogen use, cigarette smoking, and other health and lifestyle factors. To assess diet, a food-frequency questionnaire was included in the 1980, 1984, and 1986 mailings.

Food and Nutrient Assessment

The 1980 food-frequency questionnaire covered 61 food items, 6 of which were dairy foods: skim or low-fat milk, whole milk, yogurt, ice cream, cottage cheese, and hard cheese. The questionnaire was expanded for the 1984 and 1986 data collections and four dairy items were added: cream or whipped cream, sour cream, sherbet or ice milk, and cream cheese. Information on the use and daily dosage of supplemental calcium was collected in 1982 and on all subsequent biennial questionnaires.

In validation studies in which the 1980 questionnaire was compared with multiple weeks of diet records, correlations were 0.81 for skim or low-fat milk,[18] 0.62 for whole milk,[18] and 0.57 for dietary calcium.[19] We estimate that the 1980 questionnaire captures 77% and the expanded questionnaire captures 94% of the calcium intake from foods.[20(pp 72–89)]

In 1986, participants were asked to estimate the frequency of milk consump-

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tion during their teenaged years (ages 13 to 18). In a reproducibility study that compared this measure with data from a second administration 8 years later, the correlation was 0.71.

Nondietary Measures

Current weight was collected every 2 years, and body mass index (kg/m^2) was calculated for each questionnaire time period with the use of the 1976 reported height. Menopausal status, use of postmenopausal estrogen, and smoking habits were also updated on each biennial questionnaire. Questions on the use of thyroid hormone medication and thiazide diuretics were included in 1980, 1982, and 1988. In 1980, participants were asked to estimate the number of hours per weekday and weekend day that they typically spend in vigorous activity (e.g., jogging, digging in the garden, heavy housework).

Fractures

In 1982, participants were asked to report the date, description of circumstances, and exact site of all previous hip and forearm fractures. Fractures after 1982 were reported on subsequent biennial questionnaires. Only fractures of the proximal femur and distal radius that involved low or moderate amounts of trauma were included as end points in this analysis. For example, fractures due to slipping or tripping, falling on ice or snow, or falling from the height of a chair were considered low or moderate trauma events; fractures from skiing, falling down stairs, or motor vehicle accidents were coded as high trauma. About 77% of the reported fractures met the inclusion criteria.

As all study participants are registered nurses, good validity of self-reported hip and forearm fractures was expected. Indeed, in a small validation study, medical records confirmed the reported diagnosis in all 30 cases.[21]

Study Population

Of the 98 462 nurses who returned the 1980 food-frequency questionnaire, 77 761 women remained in the baseline population after the following exclusions: an implausibly low or high daily food intake or failure to report frequency of milk consumption (6%); a previous hip or forearm fracture or a diagnosis of coronary heart disease, stroke, cancer, or osteoporosis (6%); and reported use of calcium supplements in 1982 (9%).

TABLE 1—Distribution of Covariates by Frequency of Milk Consumption among 77 761 Women Aged 34 through 59 Years at Baseline in 1980

	Milk, Glasses			
	≤1/wk	2–6/wk	1/d	≥2/d
No. women	25 945	17 109	18 408	16 299
Daily dietary intakes, mean ±SD				
Calcium, mg	435 ± 198	588 ± 187	749 ± 198	1202 ± 367
Vitamin D,[a] IU	156 ± 222	222 ± 210	285 ± 210	448 ± 261
Protein, g	64 ± 24	70 ± 22	76 ± 23	91 ± 26
Phosphorus, mg	868 ± 293	1018 ± 290	1163 ± 301	1557 ± 404
Potassium, mg	2259 ± 719	2496 ± 702	2755 ± 717	3410 ± 869
Alcohol, g	7.9 ± 13	6.7 ± 11	5.9 ± 10	5.1 ± 10
Caffeine, mg	418 ± 273	396 ± 264	390 ± 266	369 ± 272
Age, y, mean ±SD	46.4 ± 6.9	46.3 ± 7.2	46.4 ± 7.3	45.8 ± 7.4
Body mass index, kg/m^2, mean ±SD	24.3 ± 4.4	24.4 ± 4.5	24.4 ± 4.4	24.6 ± 4.7
Vigorous activity, hrs/week, mean ±SD	8.8 ± 10	8.9 ± 10	9.0 ± 10	9.5 ± 10
Cigarettes, %	33.1	28.5	28.0	27.4
Postmenopausal estrogen, %[b]	17.4	18.4	17.5	18.1
Thyroid hormones, %	1.7	1.6	1.6	1.5
Thiazide diuretics, %	8.4	8.2	8.0	8.4
Drank 2 or more glasses of milk per day as a teenager	29.4	43.3	52.5	67.3

[a]Includes vitamin D from multivitamins.
[b]Percentage of users among the 32 771 women who were postmenopausal at baseline.

Analysis

Participants contributed person-time from the return date of their 1980 questionnaire until report of a hip or forearm fracture; beginning use of calcium supplements; diagnosis of osteoporosis, cancer, heart disease, or stroke; date of death; or the end of follow-up on June 1, 1992. For the nondietary exposures, person-time was allocated to the status of each variable at the beginning of each 2-year follow-up period.

In the primary analyses, women were divided into categories for frequency of milk consumption and for intake of dietary calcium based on their 1980 food-frequency questionnaire, and these measures were related to the incidence of hip and forearm fractures over the 12 years of follow-up. Frequency of milk consumption was calculated as the sum of the reported frequencies for skim or low-fat milk and for whole milk. Calcium was calculated from food sources only.

Two alternative analyses were performed that used the milk-consumption measures from the 1984 and 1986 food-frequency questionnaires in addition to the 1980 baseline measure. In the first alternative analysis, the 1980 milk intake was related to fracture incidence between 1980 and 1984; the average of the 1980 and 1984 intakes was related to fracture incidence between 1984 and 1986; and the average of the intakes on all three food-frequency questionnaires was related to fracture incidence after 1986. In the second alternative analysis, fracture incidence after 1984 among participants with high milk intakes in both 1980 and 1984 was compared with the incidence among those who had low intakes on both questionnaires.

Age-adjusted incidence rates were computed for each category of milk or calcium intake by dividing the number of fractures by the person-time of follow-up, and relative risks were computed as the incidence rate in a specific category divided by the incidence rate in the lowest group.[22] The Mantel-Haenszel test was used to examine linear trend across categories of dietary intake. Proportional hazards models were used to adjust simultaneously for potential confounding variables.[23]

TABLE 2—Relative Risks (RRs) with 95% Confidence Intervals (CIs) for Hip and Forearm Fractures, by Frequency of Milk Consumption, in a Cohort of 77 761 Women[a] Aged 34 through 59 Years at Baseline in 1980 and Followed for 12 Years

Milk, Glasses	Person-Years	Hip Fractures				Forearm Fractures			
				Multivariate				Multivariate	
		Cases	RR[b]	RR[c]	95% CI	Cases	RR[b]	RR[c]	95% CI
≤1/wk	213 264	41	1.00	1.00	. . .	342	1.00	1.00	. . .
2–6/wk	140 518	33	1.22	1.36	0.86, 2.16	235	1.06	1.04	0.88, 1.23
1/d	152 795	31	1.05	1.23	0.76, 1.98	231	0.95	0.92	0.78, 1.09
≥2/d	138 644	28	1.08	1.45	0.87, 2.43	238	1.12	1.05	0.88, 1.25
P for trend[d]			.92	.22			.26	.71	

[a]Calcium supplement users were excluded.
[b]Adjusted for questionnaire time period (2-year intervals) and age (5-year intervals).
[c]Simultaneously adjusted for questionnaire time period; age; body mass index (quintiles); menopausal status and use of postmenopausal estrogen (premenopausal, postmenopausal–never user, postmenopausal–past user, postmenopausal–current user); cigarette smoking (never, past, current); amount of vigorous activity (quintiles); use of thyroid hormone medication and thiazide diuretics (yes or no); and alcohol, caffeine, and total energy intakes (quintiles).
[d]Linear trends across categories of milk consumption with the median value used in each category.

TABLE 3—Relative Risks (RRs) with 95% Confidence Intervals (CIs) for Hip and Forearm Fractures, by Calcium Intake, in a Cohort of 77 761 Women[a] Aged 34 through 59 Years at Baseline in 1980 and Followed for 12 Years

	Person-Years	Hip Fractures			Forearm Fractures		
		Cases	RR[b]	95% CI	Cases	RR[b]	95% CI
Total dietary calcium, mg/day							
≤450	167 189	27	1.00	. . .	250	1.00	. . .
451–625	159 033	43	2.02	1.23, 3.32	256	1.02	0.85, 1.23
626–900	163 707	33	1.85	1.06, 3.22	261	0.96	0.80, 1.17
>900	155 101	30	2.04	1.12, 3.71	279	1.08	0.86, 1.33
P for trend[c]			.07			.40	
Dairy calcium, mg/day							
≤175	157 287	25	1.00	. . .	246	1.00	. . .
176–350	174 992	39	1.61	0.97, 2.68	284	1.01	0.85, 1.20
351–550	155 929	37	1.94	1.15, 3.28	235	0.92	0.76, 1.11
>550	156 824	32	1.93	1.09, 3.42	281	1.07	0.89, 1.30
P for trend[c]			.05			.41	
Nondairy calcium, mg/day							
≤200	131 938	35	1.00	. . .	186	1.00	. . .
201–275	203 891	45	0.91	0.57, 1.48	315	1.03	0.85, 1.26
276–350	166 620	23	0.66	0.36, 1.23	278	1.07	0.85, 1.33
>350	142 581	30	1.17	0.60, 2.31	267	1.12	0.87, 1.44
P for trend[c]			.29			.37	

[a]Calcium supplement users were excluded.
[b]Simultaneously adjusted for questionnaire time period (2-year intervals); age (5-year intervals); body mass index (quintiles); menopausal status and use of postmenopausal estrogen (premenopausal, postmenopausal–never user, postmenopausal–past user, postmenopausal–current user); cigarette smoking (never, past, current); and total energy intake (quintiles).
[c]Linear trends across categories of calcium intake with the median value used in each category.

Results

In 645 221 person-years of follow-up (median 8.3 years per participant), 133 hip fractures and 1046 forearm fractures due to low or moderate trauma were documented. The incidence (per 100 000 person-years) of hip fractures increased from 15 among women 40 through 44 years of age to 140 among women 65 through 69 years of age. For forearm fractures, incidence rates in these two age groups were 104 and 381, respectively.

At baseline, the frequency of milk consumption was positively associated with dietary intakes of calcium, vitamin D, protein, phosphorus, and potassium (Table 1). Women drinking more alcohol were less likely to drink milk, and women who drank milk more frequently as teen- agers were more likely to drink milk as adults. The use of calcium supplements increased sharply from 9% of the population in 1982 to 50% in 1986 and declined somewhat during the remaining follow-up period.

Adult Milk Consumption

In the 12 years of follow-up, we found no evidence to suggest a decreased

risk of hip or forearm fracture among women with greater milk intakes. In analyses adjusted only for age, the relative risks (RR) were 1.08 (95% confidence interval [CI] = 0.67, 1.75) for hip fracture and 1.12 (95% CI = 0.95, 1.32) for forearm fracture among women who consumed two or more glasses of milk per day compared with those who reported drinking milk once a week or less (Table 2). These results were not substantially altered when the analyses were adjusted for body mass index, menopausal status, use of postmenopausal estrogen, cigarette smoking, alcohol and caffeine consumption, total energy intake, and use of thyroid hormone medication and thiazide diuretics. The addition of vitamin D, protein, phosphorus, and potassium to the multivariate models yielded very similar estimates of risk although the confidence intervals were wider owing to collinearity with milk consumption.

To focus on long-term milk consumption, we limited analyses to women who reported no change in their milk consumption during the 10 years previous to the 1980 baseline assessment (n = 48 065). Results were similar to those in Table 2 for the entire cohort. We also examined the possibility that higher milk intakes might be required to protect against fractures, but found no protective effect for either hip (RR = 1.75; 95% CI 1.03, 3.00) or forearm (RR = 1.09; 95% CI 0.90, 1.32) fractures among women consuming three or more glasses of milk per day.

The ages of the fracture cases in this cohort ranged from 36 to 70 years (median = 59) for hip fractures and from 37 to 71 years (median = 56) for forearm fractures. Since it may be questionable whether the fractures in the younger women were due to low bone density, we reanalyzed our data among the women in their years after menopause (n = 264 818 person-years). However, results were not different from those presented in Table 2 for both premenopausal and postmenopausal follow-up. Even among women 60 years of age or older, two or more glasses of milk per day was not associated with a reduction in risk of hip fracture (RR = 1.27; 95% CI = 0.56, 2.92) although statistical power was low.

Lack of a protective effect from milk was substantiated by the two alternative methods of analysis that used the repeat dietary measures from 1984 and 1986 among the entire cohort of women. Using averaged measures of milk consumption from all three dietary assessments, we found no suggestion of a reduced risk of fracture of the hip (RR = 1.10; 95% CI = 0.67, 1.81) or forearm (RR = 1.05; 95% CI = 0.88, 1.24) when women in the category of two or more glasses per day were compared with those in the one or fewer glasses per week category. Also, the risks of fracture of the hip (RR = 1.31; 95% CI = 0.73, 2.35) and forearm (RR = 0.99; 95% CI = 0.80, 1.22) were not reduced among women who reported drinking one or more glasses of milk per day in both 1980 and 1984 (n = 21 231) compared with women who drank one glass or less per week during both time periods (n = 15 767).

TABLE 4—Relative Risks[a] (RRs) with 95% Confidence Intervals (CIs) for Hip and Forearm Fractures, by Frequency of Milk Consumption during Teenaged Years as Reported by 65 664 Women Aged 40 through 65 Years[b]

Milk, Glasses	Person Years	Hip Fractures			Forearm Fractures		
		Cases	RR	95% CI	Cases	RR	95% CI
≤1/wk	123 527	40	1.00	. . .	232	1.00	. . .
2–6/wk	129 749	37	0.88	0.56, 1.38	244	1.01	0.84, 1.21
1/d	134 227	32	0.71	0.44, 1.14	252	0.99	0.82, 1.19
2–3/d	293 757	76	0.82	0.55, 1.22	515	0.95	0.80, 1.11
>3/d	49 516	8	0.53	0.25, 1.16	90	0.96	0.76, 1.25
P for trend[c]			.20			.46	

[a]Simultaneously adjusted for questionnaire time period (2-year intervals); age (5-year intervals); body mass index (quintiles); menopausal status and use of postmenopausal hormones (premenopausal, postmenopausal–never user, postmenopausal–past user, postmenopausal–current user); cigarette smoking (never, past, current); and adult (1980) milk consumption.
[b]Teenage diet was reported in 1986. Hip and forearm fractures occurred between 1980 and 1992.
[c]Linear trends across categories of milk consumption with the median value used in each category.

Adult Calcium Intake

We focused our investigation on calcium from food sources, rather than total calcium intake, because the duration of calcium supplement use before 1982 was not available and because use changed considerably over the period of study, thus making the assessment of long-term effects of a calcium-supplemented diet difficult. Also, results might be confounded by those women who were taking calcium supplements because of a suspected increased risk for osteoporosis.

Calcium from all food sources was not associated with a decreased incidence of either hip (RR = 2.04; 95% CI = 1.12, 3.71) or forearm fracture (RR = 1.08; 95% CI = 0.86, 1.33) when women consuming more than 900 mg per day were compared with those with a daily intake of 450 mg or less (Table 3). Also, no protective effects were observed for the dairy and nondairy components of calcium.

Teenaged Milk Consumption

No significant association was observed between teenaged milk consumption and the risk of adult fractures (Table 4). A nonsignificant reduction in the incidence of hip fractures was found for women who consumed more than three glasses of milk per day during their teenaged years compared with those who consumed milk once a week or less (RR = 0.53; 95% CI = 0.25, 1.16) although caution is advised in interpreting these data as there were only eight hip fractures in this highest category of teenaged milk consumption and the trend over categories was not statistically significant.

To investigate the possibility that long-term milk consumption may be necessary to ensure continued bone health, women with higher intakes of milk during their teenaged years (two or more glasses per day) and in 1980 (one or more glasses per day) were compared with those who had lower intakes during both periods of life (less than one glass per day in teenaged years; one or less glasses per week as an adult). No association was observed between higher long-term milk consumption and either type of fracture (RR = 0.88; 95% CI = 0.58, 1.36 for hip fracture; RR = 1.07; 95% CI = 0.91, 1.27 for forearm fracture).

Discussion

These data suggest that more frequent milk consumption and higher dietary calcium intakes in middle-aged and older women do not provide any substantial protection against hip or forearm fractures. Increased consumption of milk and dairy foods, which are sources of both calcium and vitamin D, have been found to improve calcium balance[24] and to lower rates of bone loss in the spine[25] and femoral neck[26] in clinical trials with adult women. However, it is possible that the observed improvements were transient effects of bone remodeling that may not be sustained in the long term.[27]

Calcium is essential for building peak bone mass,[28,29] but the extent to which adult milk consumption helps to maintain bone structure is unknown. Drinking more than one glass of milk per day as an adult eliminated a positive association between lifetime caffeine intake and reduced bone densities at the hip and lumbar spine,[30] and drinking milk with every meal in adulthood was significantly associated with higher bone density at the midradius, spine, and hip.[31] However, milk consumption in childhood, adolescence, and adulthood are often highly correlated, making it difficult to determine which periods are truly responsible for the higher adult bone densities. Higher milk consumption during childhood and adolescence has been associated with higher radial, femoral, and vertebral bone densities in studies with middle-aged and older women,[32–34] while the relationships with adult milk consumption were either null or positive but not significant. Although not statistically significant, our finding of a possible beneficial effect of teenaged milk consumption on risk of adult hip fracture is compatible with these studies.

In dairy-consuming regions of China and Yugoslavia, women had higher radial bone densities[35] and a lower rate of hip fracture,[36] respectively, than women living in regions with low dairy intake. In both reports, the authors believed that the results were due to the formation of higher peak bone densities among those in the dairy regions. In fact, although the metacarpal cortical area was greater for women in the dairy region of Yugoslavia, the difference decreased with age, suggesting that higher calcium intakes did not retard age-related bone loss.

Numerous clinical studies have demonstrated reduced bone loss in the radius,[1–4] spine,[4–6] and proximal femur[4,7] with calcium supplementation, particularly in older women and when diets are low in calcium.[37,38] However, demonstrated reduction in bone loss over the 2 or 3 years of most clinical trials may not substantially alter the risk of fracture if bone remodeling reaches a new steady state[27] or if trabeculae remain disconnected.[17] A 45% reduction in vertebral fractures was reported among elderly women after 4 years of calcium supplementation,[13] but only among those who entered the study with a previous vertebral fracture, and 43% fewer hip fractures were observed after 18 months in calcium-treated women,[9] although the results cannot necessarily be attributed to calcium since the women also received a vitamin D supplement.

Of the previously published prospective population studies of calcium and hip fractures, only one reported a protective effect. Holbrook et al.[8] found a 60% reduction in the risk of hip fracture among older men and women consuming more than 765 mg/day compared with those with lower intakes. However, the study was limited by the small number of fractures (n = 33) and the use of a 1-day dietary recall to assess calcium intake during the 14 years of follow-up. Calcium did not demonstrate a protective effect in nationally representative populations in Britain[12] and the United States,[11] although the US data suggested that benefits may be limited to older postmenopausal women not on estrogen replacement therapy. Two other large prospective studies also failed to find a protective effect of calcium on hip fractures.[10,14]

In our cohort, women consuming greater amounts of calcium from dairy foods had modest but significantly increased risks of hip fracture while no increase in fracture risk was observed for the same levels of calcium from nondairy sources. We have no reason to believe that dairy calcium itself was responsible for the observed increase in risk of hip fracture; rather, some other characteristic of women who consume dairy foods or some other nutrient or nonnutrient component of dairy foods might have contributed to the elevated risk. Since protein can increase urinary calcium[39] and perhaps fracture incidence,[40] we considered the possibility that dairy protein was responsible for the increase in risk of hip fractures. However, in our cohort, higher protein intake was associated with an increased risk of forearm fracture, but no association was observed with hip fracture.[41]

With a fourfold difference in calcium intake between the 10th and 90th population percentiles, it seems unlikely that the lack of association between dietary calcium and fracture risk in our cohort can be due to insufficient variation in diet. Misclassification of calcium intake could attenuate associations, but it would not explain the positive association observed between dietary calcium and hip fractures. Also, the same food-frequency questionnaire was used to detect a clear inverse association between calcium intake and kidney stones in a population of men.[42] We cannot exclude the possibility that fracture risk might be decreased at dietary levels above those obtained in our cohort.

This study was limited by the fact that the women in our population were relatively young for hip fractures. However, we continued to see no beneficial effect of higher milk consumption on hip fracture risk even when analyses were limited to women over 60 years of age. Our cohort also exhibited relatively low age-adjusted incidence rates for hip fracture compared with those reported from national hospital discharge data,[43] which may limit the generalizability of our results.

Many of the known and suspected factors that affect bone density were measured and included in multivariate analyses. However, unmeasured factors might still confound the observed relationships between diet and fracture incidence. For example, supplemental vitamin D has been shown to reduce fracture incidence among elderly men and women,[44] and therefore measurement of sunlight exposure as a proxy for endogenous production of cholecalciferol may be an important factor in assessing fracture risk.

Recall bias is not a concern in this study since the dietary data were collected prior to fracture incidence. The recall of teenaged diet was collected after follow-up was begun, although we have no reason to assume that women would bias their recall based on their suspicion of fracture risk. To minimize this possibility, we controlled for current milk intake in the analyses. Selection bias was minimized by eliminating women who reported taking calcium supplements, since the growing public awareness of osteoporosis may have prompted calcium use disproportionately among women who believed themselves to be at the highest risk.

The results of this study are most directly applicable to middle-aged White women in the United States. Although it is possible that therapeutic levels of calcium supplementation may protect against osteoporotic fractures at particular bone sites and in defined groups of women, it is unlikely that high consumption of milk or other food sources of calcium during midlife will confer substantial protective effects against hip or forearm fractures. □

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References

1. Riis B, Thomsen K, Christiansen C. Does calcium supplementation prevent postmenopausal bone loss? a double-blind, controlled clinical study. *N Engl J Med.* 1987;316:173–177.
2. Ettinger B, Genant HK, Cann CE. Postmenopausal bone loss is prevented by treatment with low-dosage estrogen with calcium. *Ann Intern Med.* 1987;106:40–45.
3. Smith EL, Gilligan C, Smith PE, Sempos CT. Calcium supplementation and bone loss in middle-aged women. *Am J Clin Nutr.* 1989;50:833–842.
4. Dawson-Hughes B, Dallal GE, Krall EA, Sadowski L, Sahyoun N, Tannenbaum S. A controlled trial of the effect of calcium supplementation on bone density in postmenopausal women. *N Engl J Med.* 1990;323:878–883.
5. Elders PJM, Netelenbos JC, Lips P, et al. Calcium supplementation reduces vertebral bone loss in perimenopausal women: a controlled trial in 248 women between 46 and 55 years of age. *J Clin Endocrinol Metab.* 1991;73:533–540.
6. Dawson-Hughes B, Jacques P, Shipp C. Dietary calcium and bone loss from the spine in healthy postmenopausal women. *Am J Clin Nutr.* 1987;46:685–687.
7. Reid IR, Ames RW, Evans MC, Gamble GD, Sharpe SJ. The effect of calcium supplementation on bone loss in postmenopausal women. *N Engl J Med.* 1993;328:460–464.
8. Holbrook TL, Barrett-Connor E, Wingard DL. Dietary calcium and risk of hip fracture: 14 year prospective population study. *Lancet.* 1988;2:1046–1049.
9. Chapuy MC, Arlot ME, Duboeuf F, et al. Vitamin D_3 and calcium to prevent hip fractures in elderly women. *N Engl J Med.* 1992;327:1637–1642.
10. Paganini-Hill A, Chao A, Ross RK, Henderson BE. Exercise and other factors in the prevention of hip fracture: the Leisure World Study. *Epidemiology.* 1991;2:16–25.
11. Looker AC, Harris TB, Madans JH, Sempos CT. Dietary calcium and hip fracture risk: the NHANES I Epidemiologic Follow-up Study. *Osteoporos Int.* 1993;3:177–184.
12. Wickham CAC, Walsh K, Cooper C, et al. Dietary calcium, physical activity, and risk of hip fracture: a prospective study. *BMJ.* 1989;299:889–892.
13. Recker RR, Kimmel DB, Hinders S, Davies KM. Anti-fracture efficacy of calcium in elderly women. *J Bone Miner Res.* 1994;9(suppl):S154.
14. Cummings SR, Nevitt MC, Browner WS, et al. Risk factors for hip fracture in white women. *N Engl J Med.* 1995;332:767–773.
15. Hei SL, Slemenda CE, Johnston CC. Baseline measurement of bone mass predicts fracture in white women. *Ann Intern Med.* 1989;111:355–361.
16. Cummings SR, Black DM, Nevitt MC, et al. Appendicular bone density and age predict hip fractures in women. *JAMA.* 1990;263:665–668.
17. Parfitt AM. Trabecular bone architecture in the pathogenesis and prevention of fracture. *Am J Med.* 1987;82:68–72.
18. Salvini S, Hunter DJ, Sampson L, et al. Food-based validation of a dietary questionnaire: the effects of week-to-week variation in food consumption. *Int J Epidemiol.* 1989;18:858–867.
19. Willett WC, Reynolds RD, Cottrell-Hoehner S, Sampson L, Browne ML. Validation of a semiquantitative food frequency questionnaire: comparison with a 1-year diet record. *J Am Diet Assoc.* 1987;87.
20. Willett WC. *Nutritional Epidemiology.* New York, NY: Oxford University Press; 1989.
21. Colditz GA, Martin P, Stampfer MJ, et al. Validation of questionnaire information on risk factors and disease outcomes in a prospective cohort study of women. *Am J Epidemiol.* 1986;123:894–900.
22. Kleinbaum DG, Kupper LL, Morganstein H. Epidemiologic research: principles and quantitative methods. New York, NY: Van Nostrand Reinhold Co; 1982.
23. Cox DR. Regression models and life-tables. *J Royal Stat Soc.* 1972;34:187–220.
24. Recker RR, Heaney RP. The effect of milk supplements on calcium metabolism, bone metabolism and calcium balance. *Am J Clin Nutr.* 1985;41:254–263.
25. Baran D, Sorensen A, Grimes J, et al. Dietary modification with dairy products for preventing vertebral bone loss in premenopausal women: a three-year prospective study. *J Clin Endocrinol Metab.* 1990;70:264–270.
26. Nelson ME, Fisher EC, Dilmanian FA, Dallal GE, Evans WJ. A 1-y walking program and increased dietary calcium in postmenopausal women: effects on bone. *Am J Clin Nutr.* 1991;53:1304–1311.
27. Heaney RP. Nutritional factors in bone health in elderly subjects: methodological and contextual problems. *Am J Clin Nutr.* 1989;50:1182–1189.
28. Fehily AM, Coles RJ, Evans WD, Elwood PC. Factors affecting bone density in young adults. *Am J Clin Nutr.* 1992;56:579–586.
29. Johnston CC, Miller JZ, Slemenda CW, et al. Calcium supplementation and increases in bone mineral density in children. *N Engl J Med.* 1992;327:82–87.
30. Barrett-Connor E, Chang JC, Edelstein SL. Coffee-associated osteoporosis offset by daily milk consumption. *JAMA.* 1994;271:280–283.
31. Soroko S, Holbrook TL, Edelstein S, Barrett-Connor E. Lifetime milk consumption and bone mineral density in older women. *Am J Public Health.* 1994;84:1319–1322.
32. Sandler RB, Slemenda CW, LaPorte RE, et al. Postmenopausal bone density and milk consumption in childhood and adolescence. *Am J Clin Nutr.* 1985;42:270–274.
33. Stracke H, Renner G, Knie G, Leidig G, Minne H, Federlin K. Osteoporosis and bone metabolic parameters in dependence upon calcium intake through milk and milk products. *Eur J Clin Nutr.* 1993;47:617–622.
34. Murphy S, Khaw KT, May H, Compston JE. Milk consumption and bone mineral density in middle aged and elderly women. *BMJ.* 1994;308:939–941.
35. Hu JF, Zhao XH, Jia JB, Parpia B, Campbell TC. Dietary calcium and bone density among middle-aged and elderly women in China. *Am J Clin Nutr.* 1993;58:219–227.
36. Matkovic V, Kostial K, Simonovic I, Buzina R, Brodarec A, Nordin BE. Bone status and fracture rates in two regions of Yugoslavia. *Am J Clin Nutr.* 1979;32:540–549.
37. Cumming RG. Calcium intake and bone mass: a quantitative review of the evidence. *Calcif Tissue Int.* 1990;47:194–201.
38. Dawson-Hughes B. Calcium supplementation and bone loss: a review of controlled clinical trials. *Am J Clin Nutr.* 1991(suppl);54:274S–280S.
39. Hu JF, Zhao XH, Parpia B, Campbell TC. Dietary intakes and urinary excretion of calcium and acids: a cross-sectional study of women in China. *Am J Clin Nutr.* 1993;58:398–406.
40. Abelow BJ, Holford TR, Insogna KL. Cross-cultural association between dietary animal protein and hip fracture: a hypothesis. *Calcif Tissue Int.* 1992;50:14–18.
41. Feskanich D, Willett WC, Stampfer MJ, Colditz GA. Protein consumption and bone fractures in women. *Am J Epidemiol.* 1996;143:472–479.
42. Curhan GC, Willett WC, Rimm EB, Stampfer MJ. A prospective study of dietary calcium and other nutrients and the risk of symptomatic kidney stones. *N Engl J Med.* 1993;328:833–838.
43. Farmer ME, White LR, Brody JA, Bailey KR. Race and sex differences in hip fracture incidence. *Am J Public Health.* 1984;74:1374–1380.
44. Heikinheimo RJ, Inkovaara JA, Harju EJ, et al. Annual injection of vitamin D and fractures in aged bones. *Calcif Tissue Int.* 1992;51:105–110.