Dairy intakes affect bone density in the elderly\textsuperscript{1–3}

Linda D McCabe, Berdine R Martin, George P McCabe, Conrad C Johnston, Connie M Weaver, and Munro Peacock

ABSTRACT

Background: Race and sex differences in the effect of diet on bone mineral density (BMD) at the hip in the elderly are unknown.

Objectives: This study related cross-sectional nutrient and dairy product consumption to hip BMD in white and black men and women aged >60 y and evaluated the influence of nutrient and dairy product consumption on changes in BMD in a white cohort participating in a calcium, vitamin D, or placebo trial.

Design: The Health Habits and History Questionnaire was used in 289 white women and 116 white men who participated in the trial and in 265 black women and 75 black men to predict total hip and femoral neck BMD or changes in BMD.

Results: Blacks had higher calcium intakes than did whites (700 and 654 mg/d, respectively; \( P = 0.0094 \)), and men had higher calcium intakes than did women (735 and 655 mg/d, respectively; \( P = 0.0007 \)). For men, the correlation between total hip BMD and dairy calcium intake after adjustment for age, race, and weight was 0.23 (\( P < 0.005 \)); this relation was not significant in women (\( r = 0.02, P = 0.12 \)). Similar results were found for femoral neck BMD. In the longitudinal study, calcium supplementation reduced bone loss from the total hip and femoral neck in those who consumed <1.5 servings of dairy products/d and were <72 y old.

Conclusions: Cross-sectional results indicated that higher dairy product consumption is associated with greater hip BMD in men, but not in women. Calcium supplementation protected both men and women from bone loss in the longitudinal study of whites. \textit{Am J Clin Nutr} 2004;80:1066–74.

KEY WORDS Bone mineral density, diet, elderly, dairy consumption, blacks, whites, race, women, men

INTRODUCTION

Osteoporosis is a disease that affects 10 million Americans, and an additional 18 million are at risk because of low bone mass (1). More than 350 000 hip fractures are reported annually, and this number is likely to rise as the population of people >65 y old increases. Hip fracture is the most serious of the age-related osteoporotic fractures in terms of incidence, morbidity, mortality, and financial costs (1). The incidence of fractures among white women in the United States is 2–3 times that among white men, and the incidence among blacks is about one-half that among whites (1). Nutrition plays an important role in promoting and maintaining bone mass. Heaney (2) reviewed the relations between intakes of calcium and dairy products and bone mass and fractures. In 11 of 19 observational studies in the elderly, dietary calcium from supplements and dairy products was associated with either increased bone mass or decreased fracture rates. Eight of these studies were in whites, and 3 were in Asians; none were in blacks. Weinsier and Krumdieck (3) wrote, “There are too few studies in males and ethnic minorities for conclusions to be drawn about the effect of any dairy food on bone health in these groups, which together represent more than half of the US population.”

The primary objective of this study was to examine the cross-sectional relation between calcium and other nutrients from dairy product consumption and bone mineral density (BMD) at the hip in elderly black and white men and women. A second objective was to examine how consumption of calcium and dairy products relates to the effectiveness of a calcium supplement in protecting against BMD loss.

SUBJECTS AND METHODS

Subjects

White women (n = 289) and men (n = 116) from Franklin, IN (a rural community near Indianapolis), and black women (n = 265) and men (n = 75) from Indianapolis were studied. These 745 subjects were ≥60 y of age. The black subjects were recruited for a study of bone strength. The white subjects were participants in a 4-y randomized, double blind, placebo-controlled trial of a daily supplement of 750 mg Ca/d or 15 \( \mu \)g 25-hydroxyvitamin D\textsubscript{3}/d (4). Complete diet and bone information was available for 60 calcium intervention subjects, 61 vitamin D intervention subjects, and 60 placebo subjects. Black subjects from the Indianapolis study were studied in the cross-sectional analysis, and baseline data on the white subjects from the Franklin study were included in that study. White subjects in the intervention trial were studied in the longitudinal analysis. The studies were approved by the Institutional Review Board of Indiana University–Purdue University at Indianapolis. Exclusionary criteria included terminal illness; Paget’s disease of bone; recurrent urinary stone disease; treatment with sodium fluoride, bisphosphonate, steroids, or dilantin; renal disease requiring specific treatment; and disapproval by the primary physician.

1 From Purdue University, West Lafayette, IN (LDM, BRM, GPM, and CMW), and Indiana University School of Medicine, Indianapolis (CCJ and MP).

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3 Address reprint requests to CM Weaver, Department of Foods and Nutrition, Purdue University, 1264 Stone Hall, 700 West State Street, West Lafayette, IN 47907-2059. E-mail: weavercm@cfs.purdue.edu.

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Table 1

Subject characteristics of elderly black and white men and women

|           | Men                                                                 | Women                                                                  | P²       |
|-----------|---------------------------------------------------------------------|-----------------------------------------------------------------------|----------|
|           | Total (n = 745)                                                     | Black (n = 75)                                                        | White (n = 116) | Black (n = 265) | White (n = 289) | Race × sex | Blacks compared with whites | Men compared with women |
| Age (y)   | 72.75 ± 7.47                                                       | 71.25 ± 7.23ab                                                      | 75.48 ± 7.16a | 71.56 ± 7.13b  | 73.14 ± 7.67b  | <0.05     | —                          | —                      |
| Weight (kg)| 74.76 ± 15.39                                                      | 82.65 ± 14.51a                                                     | 79.99 ± 12.43ab | 77.69 ± 15.58b | 67.92 ± 13.85c | <0.05     | —                          | —                      |
| Height (cm) | 162.64 ± 9.40                                                      | 170.41 ± 13.77b                                                    | 172.88 ± 7.45a | 160.40 ± 5.76c | 158.57 ± 6.92c | <0.05     | <0.05                      | <0.05                  |
| Total hip BMD (g/cm²) | 0.912 ± 0.178                                                   | 1.097 ± 0.163                                                       | 0.982 ± 0.145 | 0.946 ± 0.161  | 0.805 ± 0.140  | —         | —                          | —                      |
| Femoral neck BMD (g/cm²) | 0.859 ± 0.166                                                   | 1.028 ± 0.152                                                       | 0.891 ± 0.143 | 0.899 ± 0.156  | 0.766 ± 0.129  | <0.05     | <0.05                      | <0.05                  |

1 All values are ± SD. BMD, bone mineral density. Values in the same row with different superscript letters are significantly different, P < 0.05 (Tukey multiple-comparison test).
2 Two-way ANOVA.

Analysis

Diet information was collected by using HHHQ-DIETSYS software (version S2.1; National Cancer Institute, Bethesda, MD) from the dietary intake portion of the Health Habits and History Questionnaire distributed by the National Cancer Institute. To better capture dairy food intake, it was necessary to adapt the questionnaire to include yogurt and frozen yogurt, and the data were analyzed by using version 3.4 of the software (5).

Table 2

Daily nutrient intake from dairy and nondairy sources in black and white elderly subjects

| Nutrient               | Dairy (n = 285) | Nondairy (n = 460) | Total diet (n = 745) |
|------------------------|-----------------|--------------------|----------------------|
| Total energy (kcal)    | 227 ± 146       | 1127 ± 398         | 1296 (829–1950)³     |
| Carbohydrate (g)       | 21 ± 15         | 135 ± 49           | 152 (95–226)         |
| Protein (g)            | 13 ± 8          | 43 ± 17            | 53 (32–82)           |
| Total fat (g)          | 10 ± 8          | 46 ± 20            | 53 (29–86)           |
| Saturated fat (g)      | 6 ± 4           | 13 ± 6             | 17 (9–31)            |
| Calcium (mg)           | 436 ± 289       | 239 ± 93           | 628 (311–1090)       |
| Calcium:phosphorus ratio | 1.24 ± 0.02 | 0.40 ± 0.09 | 0.69 (0.51–0.87)     |
| Calcium:protein ratio  | 34.24 ± 2.42    | 5.79 ± 1.74        | 12.05 (7.56–17.35)   |
| Dairy servings (no./d) | 1.41 ± 0.85     | —                  | —                    |
| Cholesterol (mg)       | 36 ± 28         | 178 ± 123          | 182 (84–374)         |
| Linoleic acid (g)      | 0.30 ± 0.24     | 11.26 ± 5.31       | 10.59 (5.51–18.78)   |
| Oleic acid (g)         | 3.04 ± 2.46     | 16.81 ± 7.68       | 18.36 (9.65–31.47)   |
| Vitamin E (α-TE)       | 0.47 ± 0.38     | 8.54 ± 5.34        | 7.73 (4.18–15.04)    |
| Vitamin A (IU)         | 647 ± 433       | 7640 ± 4746        | 7308 (3661–13 827)   |
| (RE)                   | 172 ± 119       | 1082 ± 657         | 1125 (561–2103)      |
| β-Carotene (mg)        | 66 ± 51         | 3882 ± 3167        | 3030 (1352–7345)     |
| Retinol (mg)           | 162 ± 115       | 477 ± 441          | 538 (220–1183)       |
| Provitamin A carotenoids (mg) | 66 ± 51 | 3632 ± 2596 | 3097 (1379–6455)     |
| Folate (mg)            | 15 ± 11         | 258 ± 118          | 257 (138–431)        |
| Thiamine (mg)          | 0.10 ± 0.08     | 1.11 ± 0.46        | 1.14 (0.68–1.83)     |
| Riboflavin (mg)        | 0.58 ± 0.40     | 1.03 ± 0.50        | 1.52 (0.81–2.55)     |
| Niacin (mg)            | 0.27 ± 0.21     | 14.27 ± 6.32       | 13.54 (7.64–22.77)   |
| Pyridoxine (mg)        | 0.12 ± 0.08     | 1.26 ± 0.58        | 1.27 (0.72–2.12)     |
| Vitamin C (mg)         | 2 ± 2           | 138 ± 67           | 130 (63–231)         |
| Iron (mg)              | 0.22 ± 0.18     | 9.86 ± 4.03        | 9.50 (5.51–15.48)    |
| Magnesium (mg)         | 38 ± 26         | 240 ± 169          | 227 (134–496)        |
| Phosphorus (mg)        | 352 ± 234       | 607 ± 220          | 931 (536–1419)       |
| Potassium (mg)         | 461 ± 337       | 1765 ± 630         | 2174 (1328–3160)     |
| Sodium (mg)            | 324 ± 229       | 1858 ± 735         | 2069 (1240–3255)     |
| Zinc (mg)              | 1.66 ± 1.05     | 7.30 ± 4.06        | 8.10 (4.49–13.86)    |
| Zinc from animal (mg)  | 1.66 ± 1.05     | 3.25 ± 2.07        | 4.47 (2.23–8.01)     |

1 n = 745. α-TE, α-tocopherol equivalents; RE, retinol equivalents.
2 x ± SD (all such values).
3 Median; 10th–90th percentiles in parentheses (all such values).
BMD of total hip and femoral neck were measured by using dual-energy X-ray absorptiometry (Lunar Corp, Madison, WI). After the subject was repositioned, the measurements were repeated. The CV of BMD at the total hip was 2.13%, and that of BMD at the femoral neck was 2.52% (6). A diet questionnaire was administered to the elderly white subjects, and their BMD was measured every 6 mo for 4 y.

### Statistical analysis

Two-way analysis of variance models were used to examine differences associated with sex and race. Significant interactions were found for many variables. To provide a clear and consistent exposition, Tukey’s multiple-comparison procedure was used to ascertain significant differences among the 4 sex-by-race groups. SAS software (version 8; SAS Institute, Cary, NC) was used for all statistical analyses.

For the cross-sectional study, partial correlations (7) between BMD and nutrients from dairy and nondairy sources were examined. These partial correlations quantify the strength of the linear relation between BMD and the diet variables after the linear effects of race, weight, and age are removed. They identify diet variables that have incremental predictive power. Appropriate diagnostic plots were examined to verify that these relations were approximately linear. The major interest in these analyses is in elucidating the overall pattern of the correlations, rather than in selecting and interpreting single correlations from a large collection. For this reason, no Bonferroni correction or similar adjustment was made. A partial regression plot (7) is used to visually describe this adjusted relation between total hip BMD and dairy calcium intakes in the men and the women. The partial correlation can be viewed as a quantification of the linear relation in the partial regression plot. To construct the plot, linear models for predicting total hip BMD and dairy calcium intakes by using age, weight, and race are constructed for each sex. The residuals from these models are the points plotted in the partial regression plot. For the longitudinal study, diet assessment during the 4 y of the study was evaluated by using a repeated-measures analysis of variance model. Percentage change in total hip and femoral neck BMD was evaluated by using multiple regression models in subjects who consumed > and <1.5 servings of dairy/d and in those who were older and younger than the median age of 72 y.

### TABLE 3

Total dietary nutrient intake of the 4 subgroups of elderly

| Nutrient            | Men Black | Women Black | Men White | Women White | Men compared with whites | Women compared with whites | P² |
|---------------------|-----------|-------------|-----------|-------------|--------------------------|---------------------------|----|
| Total energy (kcal) | 1776 ± 571 | 1588 ± 436  | 1300 ± 429 | 1200 ± 352  | —                        | <0.05                     | <0.05 |
| Carbohydrate (g)    | 202 ± 67  | 172 ± 46    | 155 ± 56  | 139 ± 39    | —                        | <0.05                     | <0.05 |
| Protein (g)         | 72 ± 27   | 67 ± 21     | 51 ± 18   | 51 ± 17     | —                        | —                         | <0.05 |
| Total fat (g)       | 73 ± 28   | 70 ± 24     | 52 ± 21   | 50 ± 20     | —                        | —                         | <0.05 |
| Saturated fat (g)   | 25 ± 11   | 23 ± 9      | 18 ± 8    | 16 ± 7      | —                        | —                         | <0.05 |
| Calcium (mg)        | 801 ± 400 | 693 ± 279   | 672 ± 335 | 639 ± 288   | —                        | <0.05                     | <0.05 |
| Calcium:phosphorus ratio | 0.66 ± 0.14 | 0.63 ± 0.11 | 0.72 ± 0.14 | 0.70 ± 0.13 | —                        | <0.05                     | <0.05 |
| Calcium:proportion | 11.18 ± 3.35 | 10.44 ± 3.02 | 12.91 ± 3.83 | 12.50 ± 3.95 | —                        | —                         | <0.05 |
| Cholesterol (mg)    | 312 ± 157 | 274 ± 150   | 200 ± 120 | 178 ± 110   | —                        | —                         | <0.05 |
| Linoleic acid (g)   | 13.92 ± 6.35 | 14.26 ± 4.75 | 10.74 ± 5.20 | 10.60 ± 4.92 | —                        | —                         | <0.05 |
| Oleic acid (g)      | 26.64 ± 10.20 | 24.99 ± 9.27 | 18.43 ± 7.72 | 17.31 ± 7.54 | —                        | <0.05                     | <0.05 |
| Vitamin E (α-TE) (IU) | 10.79 ± 6.47 | 11.08 ± 5.73 | 7.60 ± 4.18 | 9.01 ± 5.61 | —                        | —                         | <0.05 |
| Vitamin A (RE) (IU) | 11525 ± 7749 | 10336 ± 5381 | 7503 ± 3988 | 7344 ± 3604 | —                        | <0.05                     | <0.05 |
| β Carotene (µg)     | 6804 ± 5088b | 4576 ± 3438b | 3903 ± 2826b | 2995 ± 2026b | <0.05                    | —                         | <0.05 |
| Retinol (µg)        | 709 ± 495  | 707 ± 445   | 654 ± 479 | 579 ± 459   | —                        | —                         | <0.05 |
| Provitamin A carotenoids (µg) | 5502 ± 4381 | 4793 ± 2846 | 3196 ± 2025 | 3251 ± 1947 | —                        | —                         | <0.05 |
| Folate (µg)         | 330 ± 157  | 322 ± 116   | 246 ± 112 | 264 ± 110   | —                        | —                         | <0.05 |
| Thiamine (mg)       | 1.56 ± 0.63b | 1.38 ± 0.46b | 1.13 ± 0.45c | 1.14 ± 0.43c | <0.05                    | —                         | <0.05 |
| Riboflavin (mg)     | 1.96 ± 0.91 | 1.78 ± 0.67 | 1.51 ± 0.71 | 1.54 ± 0.66 | —                        | —                         | <0.05 |
| Niacin (mg)         | 18.58 ± 8.23 | 17.77 ± 6.40 | 12.78 ± 5.34 | 13.78 ± 5.75 | —                        | —                         | <0.05 |
| Pyridoxine (mg)     | 1.69 ± 0.78 | 1.66 ± 0.61 | 1.21 ± 0.53 | 1.33 ± 0.56 | —                        | —                         | <0.05 |
| Vitamin C (mg)      | 164 ± 84   | 151 ± 63    | 139 ± 69  | 131 ± 61    | —                        | —                         | <0.05 |
| Iron (mg)           | 12.58 ± 5.28 | 12.34 ± 3.92 | 8.94 ± 3.72 | 9.58 ± 3.44 | —                        | —                         | <0.05 |
| Magnesium (mg)      | 262 ± 90a  | 317 ± 179a  | 212 ± 78a | 326 ± 238a  | <0.05                    | —                         | <0.05 |
| Phosphorus (mg)     | 1182 ± 449 | 1090 ± 331  | 908 ± 349 | 895 ± 303   | —                        | —                         | <0.05 |
| Potassium (mg)      | 2740 ± 969 | 2558 ± 715  | 2130 ± 762 | 2046 ± 595  | <0.05                    | —                         | <0.05 |
| Sodium (mg)         | 2938 ± 1037 | 2523 ± 821  | 2132 ± 766 | 1895 ± 621  | <0.05                    | —                         | <0.05 |
| Zinc (mg)           | 11.15 ± 5.52 | 11.19 ± 4.82 | 7.60 ± 3.40 | 8.76 ± 4.31 | —                        | —                         | <0.05 |
| Zinc from animal (mg) | 6.30 ± 3.17 | 6.45 ± 2.79 | 4.21 ± 1.95 | 4.58 ± 2.13 | —                        | —                         | <0.05 |

All values are ± SD. α-TE, α-tocopherol equivalents; RE, retinol equivalents. Values in the same row with different superscript letters are significantly different, P < 0.05 (Tukey multiple-comparison test).

² Two-way ANOVA.
TABLE 4
Dairy nutrient intake of the 4 subgroups of elderly

| Nutrient                  | Black (n = 75) | White (n = 116) | Black (n = 265) | White (n = 289) | All (n = 745) | Race × sex | Blacks compared with whites | Men compared with women |
|---------------------------|---------------|-----------------|---------------|----------------|--------------|------------|---------------------------|------------------------|
| Total energy (kcal)       | 254 ± 189     | 249 ± 148       | 220 ± 148     | 217 ± 131      |              | —          | —                         | —                      |
| Carbohydrate (g)          | 22 ± 18       | 21 ± 13         | 20 ± 15       | 21 ± 15        |              | —          | —                         | —                      |
| Protein (g)               | 14 ± 10       | 13 ± 7          | 13 ± 9        | 13 ± 8         |              | —          | —                         | —                      |
| Total fat (g)             | 12 ± 9        | 12 ± 9          | 10 ± 7        | 9 ± 7          |              | —          | —                         | —                      |
| Saturated fat (g)         | 7 ± 6         | 7 ± 5           | 6 ± 4         | 5 ± 4          |              | —          | —                         | —                      |
| Calcium (mg)              | 476 ± 354     | 432 ± 242       | 429 ± 305     | 435 ± 274      |              | —          | —                         | —                      |
| Calcium:phosphorus ratio  | 1.25 ± 0.02    | 1.24 ± 0.02     | 1.25 ± 0.02   | 1.23 ± 0.03    |              | <0.05      | —                         | —                      |
| Calcium:protein ratio     | 34.18 ± 2.92  | 34.39 ± 2.39    | 34.06 ± 2.35  | 34.36 ± 2.36   |              | —          | —                         | —                      |
| Dairy servings (no/d)     | 1.44 ± 1.04   | 1.39 ± 0.68     | 1.38 ± 0.92   | 1.42 ± 0.78    |              | —          | —                         | —                      |
| Percentage dairy calcium (%)| 54 ± 17       | 59 ± 13         | 58 ± 18       | 63 ± 16        |              | <0.05      | —                         | —                      |
| Cholesterol (mg)          | 41 ± 34       | 46 ± 33         | 33 ± 25       | 34 ± 26        |              | <0.05      | —                         | <0.05                  |
| Linoleic acid (g)         | 0.39 ± 0.31   | 0.35 ± 0.24     | 0.31 ± 0.24   | 0.25 ± 0.20    |              | <0.05      | —                         | <0.05                  |
| Oleic acid (g)            | 3.59 ± 2.94   | 3.86 ± 2.85     | 2.85 ± 2.20   | 2.73 ± 2.28    |              | <0.05      | —                         | <0.05                  |
| Vitamin E (α-TE) (IU)     | 0.46 ± 0.36   | 0.48 ± 0.30     | 0.46 ± 0.38   | 0.48 ± 0.41    |              | —          | —                         | —                      |
| Vitamin A (IU)            | 742 ± 534     | 662 ± 366       | 640 ± 455     | 624 ± 405      |              | —          | —                         | —                      |
| (RE)                      | 196 ± 144     | 172 ± 97        | 171 ± 124     | 168 ± 116      |              | —          | —                         | —                      |
| β-Carotene (µg)           | 79 ± 62       | 80 ± 56         | 64 ± 49       | 58 ± 45        |              | <0.05      | —                         | —                      |
| Retinol (µg)              | 183 ± 136     | 159 ± 92        | 160 ± 118     | 159 ± 114      |              | —          | —                         | —                      |
| Provitamin A carotenoids (µg) | 79 ± 62   | 80 ± 56         | 64 ± 49       | 58 ± 45        |              | <0.05      | —                         | <0.05                  |
| Folate (µg)               | 15 ± 13       | 14 ± 9          | 14 ± 11       | 15 ± 11        |              | —          | —                         | —                      |
| Thiamine (mg)             | 0.11 ± 0.09   | 0.10 ± 0.06     | 0.10 ± 0.08   | 0.10 ± 0.08    |              | —          | —                         | —                      |
| Riboflavin (mg)           | 0.64 ± 0.50   | 0.56 ± 0.33     | 0.57 ± 0.42   | 0.58 ± 0.38    |              | —          | —                         | —                      |
| Niacin (mg)               | 0.28 ± 0.24   | 0.25 ± 0.18     | 0.26 ± 0.20   | 0.28 ± 0.22    |              | —          | —                         | —                      |
| Pyridoxine (mg)           | 0.13 ± 0.10   | 0.12 ± 0.07     | 0.12 ± 0.08   | 0.12 ± 0.08    |              | —          | —                         | —                      |
| Vitamin C (mg)            | 2 ± 2         | 2 ± 2           | 2 ± 2         | 2 ± 2          |              | —          | —                         | —                      |
| Magnesium (mg)            | 42 ± 34       | 37 ± 23         | 38 ± 28       | 37 ± 25        |              | —          | —                         | —                      |
| Phosphorus (mg)           | 380 ± 281     | 348 ± 195       | 344 ± 244     | 354 ± 226      |              | —          | —                         | —                      |
| Potassium (mg)            | 501 ± 415     | 440 ± 274       | 454 ± 345     | 465 ± 332      |              | —          | —                         | —                      |
| Sodium (mg)               | 352 ± 257     | 350 ± 229       | 315 ± 251     | 314 ± 198      |              | —          | —                         | —                      |
| Zinc (mg)                 | 1.74 ± 1.23   | 1.74 ± 0.94     | 1.58 ± 1.07   | 1.69 ± 1.02    |              | —          | —                         | —                      |
| Zinc from animal (mg)     | 1.74 ± 1.23   | 1.74 ± 0.94     | 1.58 ± 1.07   | 1.69 ± 1.02    |              | —          | —                         | —                      |

1 All values are ± SEM. α-TE, α-tocopherol equivalents; RE, retinol equivalents.
2 Two-way ANOVA.

RESULTS

Subject characteristics are shown in Table 1. The black cohort was from the urban community of Indianapolis, and the white cohort was from Franklin, IN, a more rural setting located 15 miles (24 km) from Indianapolis. The white men were the oldest of the 4 groups. The white women were the least heavy group.

TABLE 5
Percentage distribution of daily dairy product servings

| Dairy product | Black (n = 75) | White (n = 116) | Black (n = 265) | White (n = 289) | All (n = 745) | Race × sex | Blacks compared with whites | Men compared with women |
|---------------|---------------|-----------------|---------------|----------------|--------------|------------|---------------------------|------------------------|
| %            |               |                 |               |                |              |            |                           |                        |
| Ice cream     | 16 ± 2.45     | 19 ± 1.74       | 16 ± 1.27     | 14 ± 1.05      | 16 ± 0.71    | —          | —                         | —                      |
| Cheese        | 19 ± 2.44     | 20 ± 1.68       | 18 ± 1.19     | 20 ± 1.17      | 19 ± 0.71    | —          | —                         | —                      |
| Yogurt        | 4 ± 1.12      | 8 ± 1.11        | 8 ± 0.92      | 13 ± 1.04      | 9 ± 0.57     | <0.05      | —                         | <0.05                  |
| Milk          |               |                 |               |                |              |            |                           |                        |
| Beverage      | 36 ± 3.39     | 26 ± 2.46       | 30 ± 1.70     | 28 ± 1.68      | 29 ± 1.03    | —          | <0.05                     | —                      |
| On cereal     | 21 ± 2.21     | 24 ± 1.69       | 20 ± 1.20     | 23 ± 1.13      | 22 ± 0.70    | —          | —                         | —                      |
| In coffee     | 4 ± 0.80a     | 3 ± 0.92b       | 8 ± 0.82a     | 2 ± 0.44b      | 5 ± 0.39     | <0.05      | —                         | —                      |
| Total         | 100           | 100             | 100           | 100            | 100          | —          | —                         | —                      |

1 All values are ± SEM. Values in the same row with different superscript letters are significantly different, P < 0.05 (Tukey multiple-comparison test).
2 Two-way ANOVA.
TABLE 6
Percentage distribution of daily calcium intake*

| Source             | Men Black (n = 75) | Men White (n = 116) | Women Black (n = 265) | Women White (n = 289) | All (n = 745) | Racexsex | Blacks compared with whites | Men compared with women |
|--------------------|--------------------|--------------------|----------------------|----------------------|--------------|----------|---------------------|------------------------|
|                    | %                  | %                  | %                    | %                    |              |          |                     |                        |
| Dairy              | 54 ± 2.00          | 59 ± 2.00          | 58 ± 1.12            | 63 ± 0.96            | 60 ± 0.62    | —        | <0.05               | <0.05                  |
| Ice cream          | 5 ± 1.02           | 7 ± 0.76           | 5 ± 0.45             | 4 ± 0.35             | 5 ± 0.26     | —        | —                   | <0.05                  |
| Cheese             | 10 ± 1.28          | 13 ± 1.10          | 11 ± 0.66            | 12 ± 0.66            | 12 ± 0.41    | —        | <0.05               | —                      |
| Yogurt             | 2 ± 0.37           | 3 ± 0.55           | 4 ± 0.45             | 8 ± 0.64             | 5 ± 0.32     | —        | <0.05               | <0.05                  |
| Milk               |                    |                    |                      |                      |              |          |                     |                        |
| Beverage           | 24 ± 2.42          | 18 ± 1.74          | 22 ± 1.35            | 21 ± 1.32            | 21 ± 0.79    | —        | <0.05               | —                      |
| On cereal          | 11 ± 0.81          | 16 ± 0.87          | 12 ± 0.56            | 17 ± 0.69            | 14 ± 0.38    | —        | <0.05               | —                      |
| In coffee          | 2 ± 0.36b          | 2 ± 0.62b          | 4 ± 0.42a            | 1 ± 0.30b            | 3 ± 0.22     | <0.05   | —                   | —                      |
| Nondairy           | 46 ± 2.00          | 41 ± 1.20          | 42 ± 1.12            | 37 ± 0.96            | 40 ± 0.62    | —        | <0.05               | <0.05                  |
| Total              | 100                | 100                | 100                  | 100                  | 100          | 100      |                     |                         |

* All values are ± SEM. Values in the same row with different superscript letters are significantly different, P < 0.05 (Tukey multiple-comparison test).

Two-way ANOVA.

TABLE 7
Partial correlations of total hip bone mineral density with daily nutrients from dairy and nondairy foods in the elderly*

| Source             | Black and white men (n = 191) | Black and white women (n = 554) |
|--------------------|-------------------------------|---------------------------------|
|                    | Dairy                        | Nondairy                        | Total diet         | Dairy                        | Nondairy                        | Total diet         |
|                    |                               |                                 |                   |                               |                                 |                   |
| Total energy (kcal)| 0.18                       | 0.05                            | 0.10              | 0.02                          | 0.02                            | 0.02              |
| Carbohydrate (g)   | 0.15                       | 0.04                            | 0.08              | −0.00                         | −0.01                           | −0.01             |
| Protein (g)        | 0.23                       | 0.06                            | 0.13              | 0.02                          | 0.02                            | 0.03              |
| Total fat (g)      | 0.15                       | 0.05                            | 0.09              | 0.04                          | 0.04                            | 0.05              |
| Saturated fat (g)  | 0.15                       | 0.04                            | 0.11              | 0.04                          | 0.03                            | 0.04              |
| Calcium (mg)       | 0.23                       | 0.09                            | 0.22              | 0.02                          | 0.02                            | 0.02              |
| Calcium:phosphorus ratio | 0.02                  | 0.02                            | 0.19              | 0.03                          | 0.06                            | 0.04              |
| Calcium:protein ratio | −0.11                     | −0.01                           | 0.15              | −0.04                         | −0.05                           | −0.03             |
| Dairy servings (no./d) | 0.19                     |                                 |                   | 0.02                          |                                 |                   |
| Percentage dairy calcium (%) | 0.17                   |                                 |                   | 0.00                          |                                 |                   |
| Cholesterol (mg)   | 0.16                       | 0.03                            | 0.06              | 0.04                          | −0.00                           | 0.01              |
| Linoleic acid (g)  | 0.14                       | 0.03                            | 0.03              | 0.04                          | 0.02                            | 0.02              |
| Oleic acid (g)     | 0.15                       | 0.04                            | 0.08              | 0.04                          | 0.04                            | 0.04              |
| Vitamin E (α-TE)   | 0.13                       | 0.06                            | 0.06              | −0.02                         | 0.03                            | 0.02              |
| Vitamin A (IU)     | 0.20                       | 0.03                            | 0.04              | 0.03                          | −0.05                           | −0.04             |
| (RE)               | 0.20                       | 0.00                            | 0.03              | 0.02                          | −0.05                           | −0.05             |
| β-Carotene (μg)    | 0.15                       | 0.05                            | 0.05              | 0.03                          | −0.02                           | −0.01             |
| Retinol (μg)       | 0.20                       | −0.06                           | −0.01             | 0.02                          | −0.05                           | −0.04             |
| Provitamin A carotenoids (μg) | 0.15             | 0.04                            | 0.05              | 0.03                          | −0.03                           | −0.03             |
| Folate (μg)        | 0.23                       | 0.05                            | 0.07              | 0.01                          | 0.01                            | 0.01              |
| Thiamine (mg)      | 0.21                       | 0.03                            | 0.05              | 0.02                          | 0.02                            | 0.03              |
| Riboflavin (mg)    | 0.22                       | 0.02                            | 0.13              | 0.02                          | 0.00                            | 0.01              |
| Niacin (mg)        | 0.23                       | 0.05                            | 0.06              | 0.02                          | 0.02                            | 0.02              |
| Pyridoxine (mg)    | 0.22                       | 0.05                            | 0.07              | 0.02                          | 0.01                            | 0.02              |
| Vitamin C (mg)     | 0.21                       | 0.06                            | 0.07              | 0.04                          | −0.04                           | −0.03             |
| Iron (mg)          | 0.11                       | 0.04                            | 0.04              | 0.01                          | 0.02                            | 0.02              |
| Magnesium (mg)     | 0.21                       | 0.15                            | 0.18              | 0.03                          | 0.02                            | 0.03              |
| Phosphorus (mg)    | 0.23                       | 0.05                            | 0.17              | 0.02                          | 0.02                            | 0.03              |
| Sodium (mg)        | 0.21                       | 0.06                            | 0.13              | 0.02                          | −0.02                           | −0.01             |
| Zinc (mg)          | 0.20                       | 0.06                            | 0.09              | 0.01                          | 0.03                            | 0.03              |
| Zinc from animal (mg) | 0.20                       | 0.02                            | 0.09              | 0.01                          | 0.01                            | 0.01              |

* α-TE, α-tocopherol equivalents; RE, retinol equivalents. Correlations are adjusted for age, race, and weight.

P < 0.05.
The black women weighed less than the black men but not less than the white men. For both total hip and femoral neck BMD, the blacks had higher values than did the whites, and the men had higher values than did the women.

Cross-sectional study

The mean calcium intake from dairy and nondairy sources was 436 mg/d and 239 mg/d, respectively (Table 2). Dairy sources supplied 60% of the daily calcium intake, whereas all other nutrients were derived primarily from nondairy sources (Table 2). Dairy products were also an important source of phosphorus, riboflavin, retinol, and saturated fat, supplying >30% of the daily intake of these nutrients.

The blacks had higher calcium intakes than did the whites (700 and 654 mg/d, respectively; \( P = 0.0094 \)), and the men had higher calcium intakes than did the women (735 and 655 mg/d, respectively; \( P = 0.0007 \)), as shown in Table 3, but calcium intakes from dairy sources did not differ significantly by sex, as shown in Table 4. The men consumed more total energy (1662 compared with 1247 kcal) and energy from dairy sources (251 compared with 219 kcal) than did the women and, consequently, consumed more nutrients. The blacks consumed more total energy than did the whites (1405 compared with 1311 kcal), but energy from dairy sources did not differ significantly.

Milk that was consumed in coffee, on cereal, and as a beverage was the most popular dairy product for all groups, accounting for 53–61% of total dairy servings per day (Table 5). Similarly, in terms of calcium intake (in mg), fluid milk accounted for 38% of the total calcium intake and 63% of the dairy calcium intake (Table 6). The blacks consumed more glasses of milk than did the whites. Yogurt was consumed by the women more than by the men and by the whites more than by the blacks. Dairy calcium intake was unrelated to age, race, sex, or weight (data not shown).

To examine the relations between diet and bone measures, we took into account the fact that the subjects were not all the same age, race, sex, and weight, as discussed in Subjects and Methods. The effect of diet on bone measures did not depend on race; the race-by-diet interactions were not significant (total hip: \( F_{1,737} = 0.004, P = 0.95 \); femoral neck: \( F_{1,737} = 0.08, P = 0.78 \)). However, the sex-by-diet interactions were statistically significant (total hip: \( F_{1,737} = 6.81, P = 0.0092 \); femoral neck: \( F_{1,737} = 3.96, P = 0.0465 \)). We therefore presented separate analyses for the men and the women. Results for total hip BMD are given in Table 7. A positive partial correlation between total hip BMD and dairy calcium intake was found in the men (\( r = 0.23 \)) but not in the women (\( r = 0.02 \)). These partial correlations are depicted in the partial regression plots shown in Figure 1. The line with the positive slope describes the relation in the men, and the line that is essentially flat describes the relation in the women. There was no relation with nondairy calcium intake. In the men only, positive relations were found between both total hip and femoral neck BMD (Table 8) and dairy sources of total energy, carbohydrate, protein, vitamin A, retinol, folate, thiamine, riboflavin, niacin, vitamin B-6, vitamin C, magnesium, potassium, sodium, and zinc.

Regression analysis showed that age, weight, and race explained 29% (\( P < 0.0001 \)) of the variation in total hip BMD in the men and 44% (\( P < 0.0001 \)) of that in the women. For femoral neck BMD, the corresponding values are 33% (\( P < 0.0001 \)) and 42% (\( P < 0.0001 \)), respectively. Higher bone densities were associated with subjects who were younger, heavier, black, and male. Many nutrients from dairy sources strengthened the prediction of total body and femoral neck BMD in the regression model, whereas nutrients from nondairy sources did not improve the prediction. Nutrients with similar partial correlations can be interchanged in the predictive equation.
### TABLE 8
Partial correlations of femoral neck bone mineral density with daily nutrients from dairy and nondairy foods in the elderly

|                     | Black and white men ($n = 191$) | Black and white women ($n = 554$) |
|---------------------|----------------------------------|-----------------------------------|
|                     | Dairy                            | Nondairy                          | Total diet                          |
|                     | Dairy                            | Nondairy                          | Total diet                          |
| Total energy (kcal) | 0.15$^2$                        | 0.06                              | 0.10                                | 0.07                              | 0.01                              | 0.04                              |
| Carbohydrate (g)    | 0.15$^2$                        | 0.06                              | 0.10                                | 0.03                              | -0.00                             | 0.01                              |
| Protein (g)         | 0.21$^2$                        | 0.06                              | 0.12                                | 0.07                              | 0.02                              | 0.05                              |
| Total fat (g)       | 0.11                            | 0.07                              | 0.09                                | 0.09$^a$                          | 0.03                              | 0.05                              |
| Saturated fat (g)   | 0.11                            | 0.04                              | 0.08                                | 0.09$^a$                          | 0.01                              | 0.06                              |
| Calcium (mg)        | 0.21$^2$                        | 0.12                              | 0.22$^2$                            | 0.07                              | -0.03                             | 0.05                              |
| Calcium:phosphorus ratio | -0.06                        | 0.04                              | 0.17$^2$                            | 0.03                              | -0.09$^2$                         | -0.00                             |
| Calcium:protein ratio | -0.03                       | 0.04                              | 0.16$^2$                            | -0.06                             | -0.07                             | 0.01                              |
| Dairy servings (no./d) | 0.18$^2$                     | 0.06                              |                                     |                                    |                                   |                                   |
| Percentage dairy calcium (%) | 0.14$^2$                   | 0.06                              |                                     |                                    |                                   |                                   |
| Cholesterol (mg)    | 0.12                            | 0.00                              | 0.03                                | 0.09$^a$                          | 0.00                              | 0.02                              |
| Linoleic acid (g)   | 0.10                            | 0.06                              | 0.06                                | 0.09$^a$                          | 0.02                              | 0.02                              |
| Oleic acid (g)      | 0.11                            | 0.06                              | 0.08                                | 0.09$^a$                          | 0.01                              | 0.04                              |
| Vitamin E (α-TE)    | 0.11                            | 0.12                              | 0.12                                | 0.04                              | 0.03                              | 0.04                              |
| Vitamin A (RE)      | 0.19$^2$                        | 0.04                              | 0.05                                | 0.06                              | -0.04                             | -0.03                             |
| β-Carotene (µg)     | 0.20$^2$                        | 0.01                              | 0.04                                | 0.05                              | -0.05                             | -0.04                             |
| Retinol (µg)        | 0.20$^2$                        | -0.06                             | -0.01                               | 0.05                              | -0.05                             | -0.04                             |
| Provitamin A carotenoids (µg) | 0.10                       | 0.06                              | 0.06                                | 0.09$^a$                          | -0.02                             | -0.01                             |
| Folate (µg)         | 0.21$^2$                        | 0.08                              | 0.10                                | 0.06                              | 0.01                              | 0.01                              |
| Thiamine (mg)       | 0.21$^2$                        | 0.04                              | 0.07                                | 0.05                              | 0.04                              | 0.04                              |
| Riboflavin (mg)     | 0.21$^2$                        | 0.04                              | 0.14                                | 0.06                              | -0.01                             | 0.03                              |
| Nicin (mg)          | 0.22$^2$                        | 0.08                              | 0.09                                | 0.06                              | 0.01                              | 0.01                              |
| Pyridoxine (mg)     | 0.21$^2$                        | 0.06                              | 0.09                                | 0.06                              | 0.02                              | 0.03                              |
| Vitamin C (mg)      | 0.17$^2$                        | 0.06                              | 0.06                                | 0.09$^a$                          | -0.03                             | -0.03                             |
| Iron (mg)           | 0.11                            | 0.06                              | 0.06                                | 0.05                              | 0.03                              | 0.04                              |
| Magnesium (mg)      | 0.20$^2$                        | 0.19$^2$                          | 0.21$^2$                            | 0.07                              | 0.02                              | 0.03                              |
| Phosphorus (mg)     | 0.21$^2$                        | 0.06                              | 0.17$^2$                            | 0.06                              | 0.02                              | 0.06                              |
| Potassium (mg)      | 0.20$^2$                        | 0.06                              | 0.13                                | 0.05                              | -0.01                             | 0.02                              |
| Sodium (mg)         | 0.15$^2$                        | 0.12                              | 0.14                                | 0.07                              | -0.02                             | 0.01                              |
| Zinc (mg)           | 0.19$^2$                        | 0.07                              | 0.10                                | 0.06                              | 0.03                              | 0.04                              |
| Zinc from animal (mg) | 0.19$^2$                     | -0.01                             | 0.06                                | 0.06                              | 0.01                              | 0.04                              |

$^a$α-TE, α-tocopherol equivalents; RE, retinol equivalents. Correlations are adjusted for age, race, and weight.

$^2 P < 0.05.$

**Longitudinal study**

No differences in dairy servings consumed were found between the groups or over time (data not shown). Subjects were classified into 2 groups on the basis of whether they consumed >1.5 or ≤1.5 servings of dairy products/d. This cutoff value was chosen on the assumption that, if milk was the sole contribution to dietary calcium, 1.5 servings would provide 450 mg Ca and, together with the 750 mg Ca from the supplement, that amount would increase the calcium intake to the 1200 mg/d requirement for this age group. The effect of the calcium supplement on percentage change in femoral neck BMD depended on dietary calcium intake ($P < 0.05$ for interaction; Figure 2). The treatment effect was evident in those who had deficient diets (<1.5 servings of dairy products/d or <450 mg/d at baseline) but not in those with calcium intakes ≥1.5 servings of dairy products/d. Those subjects who consumed <1.5 servings of dairy products/d at baseline and were assigned to the placebo group lost >2% BMD at the femoral neck. A similar effect was observed for total hip BMD.

For femoral neck BMD, the effect of calcium supplementation was evident in those <72 y old at the start of the study ($P < 0.05$), but not in those >72 y old ($P < 0.05$ for interaction; Figure 3). Similar results were obtained for total hip BMD.

**DISCUSSION**

In this cross-sectional study, a significant positive relation was observed between dairy nutrient consumption and BMD at the total hip and femoral neck in white and black elderly men, but not in white and black elderly women. Most of the previous studies examining the relation between diet and BMD were in white postmenopausal women. The nutrient most often predictive of BMD (2) and the one most likely to be deficient in the diet is calcium. The median calcium intake in this sample was only 52.3% of the 1200 mg/d recommended for this age group (8). In contrast to the nationally representative sample of men and women >60 y old, the third National Health and Nutrition Examination Survey (9), in which blacks had lower calcium intakes
women supplemented with 750 mg Ca/d (\(\text{change in femoral neck bone mineral density (BMD)}\) in 121 white men and women supplemented with 750 mg Ca/d (•) or placebo (□) over 4 y (\(P < 0.05\)). A general linear model analysis was used to predict percentage change in femoral neck BMD with calcium intervention, baseline dairy intake, and the interaction between calcium intervention and dairy intake (\(P < 0.05\)). Sample sizes were as follows: calcium and <1.5 dairy servings, \(n = 36\); calcium and ≥1.5 dairy servings, \(n = 34\); and placebo and <1.5 dairy servings, \(n = 26\). Bars equal SEs.

than did whites, the blacks in the current study had higher calcium intakes than did the whites, and the men had higher calcium intakes than did the women. A meta-analysis of osteoporotic fractures in postmenopausal women estimated an odds ratio of 0.96 (95% CI: 0.93, 0.99) for each 300-mg increase in calcium per day (10). Another meta-analysis of 15 controlled trials in postmenopausal women found that calcium supplementation reduced BMD loss at the hip by an average of 1.64% more than in placebo groups, and there was a relative risk of 0.77 (95% CI: 0.54, 1.09) for vertebral fractures and of 0.86 (95% CI: 0.43, 1.72) for nonvertebral fractures (11). Calcium and vitamin D supplementation reduced total-body bone loss in both elderly men and women in a 3-y randomized controlled trial, but the effect on the femoral neck was significant only in the men (12). In the calcium intervention study in the white cohort reported here, we found that calcium supplementation was effective in preventing a decline in total hip and femoral neck BMD in both men and women (4). Despite the benefit of calcium intervention, dairy intake was not significantly related cross-sectionally to BMD in the same women. Others have also reported no significant relation in cross-sectional analysis between calcium intake and BMD or hip fracture risk (13, 14). The discrepancy between predictive behavior based on food-frequency questionnaires and the observed benefit of calcium supplementation in the women contrasted with that in the men may suggest that women are more likely to underreport calcium intake than are men. Underreporting of energy intake increased with increasing energy expenditure in women but not in men in a study that quantified inaccuracies in self-reported energy intakes identified by comparison with double-labeled water determination of energy expenditure (15). Almost all of the nutrients in milk were related to BMD in men but not in women. The pattern of correlations among the dairy intake variables is such that we cannot attribute the effect to a single nutrient after additional adjustment. This is consistent with a scenario in which the factors responsible for the relation in men may be factors other than—or in addition to—calcium.

Other studies have not compared nutrients from dairy sources with nutrients from the total diet. We found that many nutrients from dairy foods are significantly correlated with total hip and femoral neck BMD in men but not in women, whereas nondairy nutrients are not significantly correlated. Similarly, the addition of dairy nutrient intake but not nondairy nutrient intake to regression models strengthened the prediction of BMD. A limitation of this study is that nutrients contributed by dairy sources as part of mixed foods were not captured, and, thus, the strength of the relation may be underestimated. When total diet nutrients are examined, only daily calcium intakes (or the ratio of calcium to protein or calcium to phosphorus) and daily intakes of magnesium, phosphorus, and sodium significantly correlated with total hip BMD in men. Because dairy food consumption in men significantly correlated with total hip and femoral neck BMD, any nutrient that is a marker for dairy food consumption will be predictive of BMD but may not have a unique role in maintaining BMD. However, dairy products contributed <20% of the total intake of these nutrients except for calcium (64.6%), phosphorus (36.7%), saturated fat (31.3%), retinol (25.3%), protein (22.8%), and potassium (20.7%). In a dairy intervention study, the addition of 3 servings of milk/d significantly increased intakes of calcium, protein, phosphorus, magnesium, and vitamin D in men and women aged 55–85 y (16). In contrast to the findings in the elderly population reported here, dairy product consumption was a stronger predictor of BMD in a population of Chinese women than was either calcium or protein intake (17). It is possible that dairy consumption is a marker for a generally healthier lifestyle in the US population.
A limitation of our study is that the database of the HHHQ did not contain vitamin D. Approximately 2 μg vitamin D/d would have come from fortified milk, an amount that is comparable to the 5 μg vitamin D/d consumed from food by a large sample of postmenopausal women, half of which came from fortified milk (14). Vitamin D status averaged 60.5 nmol/L in our longitudinal cohort (4).

An analysis of usual dairy product consumption contributed to our understanding of which subjects responded to calcium supplementation in the intervention trial. Lower consumption of dairy products resulted in more benefit from calcium supplementation during the 4-y study with respect to reducing bone loss in the total hip and femoral neck. The benefit of supplementation decreased after age 72 y. Considering the large numbers of dairy nutrients that were positively related to bone health in the cross-sectional study, it would be expected that consumption of adequate dairy products would be more beneficial than supplementation with 1 or 2 individual nutrients.

In this study of elderly black and white men and women, dairy nutrients contributed significantly and interchangeably to a predictive model of total hip and femoral neck BMD that included weight, age, race, and sex. Milk was the primary source of calcium in all groups. All subjects ingested calcium at intakes well below the requirement for this age group, but the insufficiency was least in the black men. Dairy consumption predicted total hip BMD in the black men but not in the white men and not in the women of either race. Nevertheless, a calcium supplementation intervention was equally effective in protecting against bone loss in the white men and women. Elderly who had lower previous dairy intakes and who were younger than 72 y experienced the greatest positive benefit of calcium supplementation. Overall, this study suggests a positive role for dairy foods in the diet of the elderly.

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