# Previous milk consumption is associated with greater bone density in young women[1–3]

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**ABSTRACT**

**Background:** Dietary calcium and milk intakes at specific ages may influence bone mineral measures at specific sites during development of peak bone mass.

**Objective:** Relations of previous milk intake and current calcium intake to current bone mineral measures were investigated in young women.

**Design:** A food-frequency interview and recall of previous milk intake from early childhood to 12 y of age and during adolescence (13–19 y) were completed in a cross-sectional analysis in young women (age 18–31 y; $n$ = 224). Three levels of previous milk intake were defined: *1*) infrequently or never, *2*) sometimes, and *3*) at every or almost every meal. Total body (TB), femoral neck, radius (R), and spine (S) bone mineral density (BMD) and bone mineral content (BMC) were determined by using dual-energy X-ray absorptiometry.

**Results:** Childhood and adolescent milk intakes were positively correlated ($r = 0.66$). Childhood and adolescent milk intakes correlated with current calcium intakes ($r$ = 0.26 and 0.33, respectively). Adolescent milk intake correlated with RBMD ($r = 0.16$). When weight was controlled for, adolescent milk intake correlated with TBBMD ($r = 0.16$), TBBMC ($r = 0.21$), SBMC ($r = 0.16$), RBMD ($r = 0.18$), and RBMC ($r = 0.15$). Current calcium intakes correlated with SBMC ($r = 0.17$). Regression analyses supported these results.

**Conclusions:** Results were consistent with the hypothesis that higher milk intake during adolescence is associated with greater total body, spine, and radial bone mineral measures during development of peak bone mass, whereas current calcium intakes may influence SBMC. In addition, milk intake at a younger age may contribute to similar habits of milk intake later in life. *Am J Clin Nutr* 1999;69:1014–7.

**KEY WORDS** Bone density, diet, premenopausal women, adolescence, calcium, milk, dairy, childhood, dual-energy X-ray absorptiometry, bone mineral content, bone mineral density

## INTRODUCTION

Osteoporosis is characterized by reduced bone mass. Postmenopausal bone mass is determined by both peak bone mass attained early in life and the rate of loss of bone mass later in life. Increasing the peak bone mass attained may therefore reduce the incidence of osteoporosis. The age at which peak bone mass is achieved is not certain. Estimates of attainment of peak total-body (TB) bone mineral density (BMD) and bone mineral content (BMC) range from age 18 y to the 20s (1–3). Several studies have examined the age at which peak bone mass is attained at specific sites, particularly the radius, lumbar spine, and femoral neck (3–11). Most studies suggest that peak femoral neck BMD (NBMD) is achieved by the age of 14–18 y (4, 8). The age at which peak bone mass is achieved in the spine is unclear, with estimates varying from 14 y to the fourth decade (3, 4, 8). Thus, specific sites may achieve peak mass differentially, and the effect of dietary intake at different ages may also vary depending on the bone site.

The influence of calcium intake on bone mass at various phases of growth remains uncertain, although recent intervention studies suggest that increased calcium intake can significantly improve bone mass in childhood (12–14) and adolescence (12, 15–17). When calcium supplementation is stopped, the improvement achieved during supplementation may not be sustained (18). It is as yet unclear how these increases in bone mass during childhood and adolescence affect the attainment of peak bone mass, which occurs for most sites between the ages of 18 and 30 y.

No studies to date have examined in one model the impact of childhood, adolescent, and current calcium intakes on the attainment of peak bone mass at varied sites. This could be due, in part, to methodologic problems associated with determining childhood intake in adults retrospectively. However, it is well accepted that milk supplies ≈60–75% of the daily calcium intake in the American population; therefore, a recall of milk intakes can approximate the calcium intake at different periods of growth (19).

A previous study showed that milk intake in childhood and adolescence may influence postmenopausal bone mass (20). In

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addition, women with a high intake of milk in childhood and adolescence had higher intakes of milk in later life than did women with a low intake at a younger age (20). No studies have addressed the question of the cumulative effect of childhood, adolescent, and young-adult calcium and milk intakes on the attainment of peak bone mass.

The current study investigated the relation of milk intake during childhood and adolescence and current calcium intake to peak bone mass in young women. Determining the age and other factors, such as calcium intake, that influence the development of a peak bone mass that is consistent with genetic potential, is necessary for the formulation of strategies to optimize bone mass and reduce the incidence of osteoporosis in later life.

## SUBJECTS AND METHODS

White women ($n$ = 224, aged 18–31 y) were recruited through direct mailings, radio announcements, and fliers for an exercise intervention study. The cross-sectional data used in this study are baseline data for the exercise intervention study and were collected over a 3-y period during all seasons of the year. The study protocol was approved by the Purdue University Institutional Review Board.

### Exclusion criteria

Exclusion criteria included chronic intake of medication that interferes with calcium metabolism, irregular menses, or a history of high blood pressure, heart disease, or diabetes. None of the participants were elite athletes and none had participated in >2 h exercise/wk in the prior year.

### Dietary intake and lifestyle factors

Current dietary intake was assessed by a food-frequency interview (21) that included assessment of intake of calcium supplements. Previous milk intake from early childhood to 12 y of age and during adolescence (13–19 y of age) was assessed by recall. Both the interview and recall were administered by 2 trained nutritionists. Three levels of previous milk intake were defined: *1*) infrequently or never, *2*) sometimes, and *3*) at every or almost every meal.

### Bone mass and anthropometric measurements

Weight was measured with a calibrated electronic scale and height was measured with a wall-mounted stadiometer with subjects wearing light clothing and no shoes. TB-, spine (S-), and NBMD were assessed with a dual-energy X-ray absorptiometer (DPXL; Lunar Corp, Madison, WI). Short-term precision was determined by the SD of 2 measurements repeated on the same day divided by the mean. Short-term precision for adults was 1% for SBMD and 1.4% for NBMD. The radial (R) BMD and BMC were assessed with use of a single-photon absorptiometer (SPA; Lunar SP2; Lunar Corp). The short-term precision of single-photon absorptiometry at the midshaft radius is 1.6%. Data are expressed as g/cm$^2$ for SBMD, RBMD, NBMD, and TBBMD, as g for TBBMC and SBMC, and as g/cm for RBMC.

### Statistical analysis

Means, SDs, and correlations were computed for all variables. Multivariate and univariate regression methods were used to relate bone measures to previous milk intake (categoric variables) and current calcium intake (mg/d). Because weight is such a strong predictor of bone mass, analyses were done both with and without adjustment for weight. All computations were performed by using SAS statistical software (22). Results were considered significant when $P < 0.05$; $P$ values between 0.05 and 0.10 were considered a trend.

**TABLE 1**
Subject characteristics[1]

| Characteristic | Value |
|---|---|
| Age (y) | 23.3 ± 3.7 (18.0–31.0) |
| Weight (kg) | 62.8 ± 10.6 (35.0–91.0) |
| Height (cm) | 165.4 ± 7.31 (147.3–185.4) |
| Total body fat (%) | 33.5 ± 8.2 (12.4–49.4) |
| Total-body lean mass (kg) | 39.0 ± 4.2 (26.9–51.4) |
| Total-body BMD (g/cm$^2$) | 1.157 ± 0.077 (0.996–1.372) |
| Total-body BMC (g) | 2549 ± 373 (1667–3765) |
| Radius BMD (g/cm$^2$) | 0.691 ± 0.050 (0.552–0.836) |
| Radius BMC (g/cm) | 0.854 ± 0.101 (0.638–1.126) |
| Spine BMD (g/cm$^2$) | 1.234 ± 0.136 (0.957–1.652) |
| Spine BMC (g) | 49.46 ± 8.89 (32.42–79.15) |
| Femoral neck BMD (g/cm$^2$) | 1.010 ± 0.123 (0.779–1.479) |
| Current calcium intake (mg/d) | 958 ± 469 (251–3273) |

[1] $\bar{x}$ ± SD; range in parentheses. BMD, bone mineral density; BMC, bone mineral content.

## RESULTS

Subject characteristics are shown in **Table 1**. There was a wide range of current calcium intakes (251–3273 mg/d). The frequency of milk intake at 3 levels during childhood and adolescence is shown in **Table 2**. Most of the subjects drank milk at every or almost every meal (level 3), although the frequency of regular milk intake declined in adolescence (63%) compared with early childhood (78%). Childhood and adolescent milk intakes were correlated with current calcium intake ($r$ = 0.26 and $r$ = 0.33, respectively, $P < 0.0001$), as well as with each other ($r$ = 0.66, $P < 0.0001$).

The correlations of previous milk intakes and current calcium intake with bone mineral measures with and without controlling for weight are shown in **Table 3**. When weight was not controlled for, childhood milk intake was not related to any bone mineral measure, and adolescent intake was only related to RBMD (Table 3). However, when weight was controlled for, childhood intake correlated with TBBMC and significant correlations emerged between adolescent milk intake and TBBMD, TBBMC, SBMC, RBMD, and RBMC. Current calcium intake correlated with SBMC with a trend noted for SBMD and RBMD. These results did not change when weight was controlled for.

Results of regression models for predicting bone mass at various sites with weight, frequency of childhood and adolescent milk

**TABLE 2**
Frequency of milk intake in childhood and adolescence

| | Milk intake level | | |
|---|---|---|---|
| Previous milk intakes | Infrequently or never | Sometimes | Every or almost every meal |
| | | *n (%)* | |
| Childhood | 21 (9) | 29 (13) | 174 (78) |
| Adolescence | 42 (19) | 40 (18) | 142 (63) |

**TABLE 3**
Unadjusted and adjusted correlations of previous milk and current calcium intakes with bone mineral measures[1]

| | Previous milk intakes | | Current calcium |
|---|---|---|---|
| | Childhood | Adolescence | intake |
| Total body | | | |
| BMD | −0.02 (0.04) | 0.10 (0.16)[2] | 0.05 (0.06) |
| BMC | 0.02 (0.14)[2] | 0.10 (0.21)[2] | 0.01 (0.01) |
| Spine | | | |
| BMD | −0.02 (0.01) | 0.08 (0.11) | 0.11[3] (0.12)[3] |
| BMC | 0.02 (0.08) | 0.11[3] (0.16)[2] | 0.14[2] (0.17)[2] |
| Femoral neck BMD | −0.01 (0.02) | 0.06 (0.08) | 0.06 (0.05) |
| Radius | | | |
| BMD | 0.03 (0.07) | 0.16[2] (0.18)[2] | 0.11[3] (0.12)[3] |
| BMC | 0.07 (0.11)[3] | 0.12[3] (0.15)[2] | 0.04 (0.05) |

[1]Correlation coefficients ($r$) adjusted for weight in parentheses. BMD, bone mineral density; BMC, bone mineral content.
[2]$P < 0.05$.
[3]$0.10 > P > 0.05$.

intake, and current calcium intake are shown in **Table 4**. Childhood milk intake did not predict any bone measure. In addition, neither previous milk intake nor current calcium intake predicted NBMD or SBMD. Adolescent intake predicted TBBMD, TBBMC, RBMD, and RBMC; current calcium intake predicted SBMC. When the "infrequently or never" and the "sometimes" childhood and adolescent milk intake categories were combined, the results of the correlational and regression analyses were the same.

## DISCUSSION

Given that weight is a significant predictor of bone mass, the results of this study show the additional importance of milk and calcium intake in attaining maximum peak bone mass. In this cross-sectional study, adolescent milk intake predicted TBBMD, TBBMC, RBMD, and RBMC in 18–31-y-old women after weight was controlled for. In addition, current calcium intake predicted SBMC. On the other hand, none of these dietary variables predicted NBMD. To our knowledge, this is the first study to investigate the relation of childhood and adolescent milk intakes to the attainment of peak bone mass.

The lack of a relation between childhood milk intake and bone mineral measures may be due to the reliability of recall questions, although there was a strong correlation between childhood and adolescent milk intakes ($r$ = 0.66). It is likely that this age group would recall adolescent milk intake frequency more reliably because they were within 1–10 y of the period of time recalled. Furthermore, adolescent milk intake was sufficient to predict BMD and BMC at several bone sites, suggesting that the recall of this measure provided sufficient information. The relations of childhood and adolescent milk intakes with current calcium intake suggest that the early establishment of dietary habits that include milk intake promote a higher intake of calcium in young women.

The results of the current study are consistent with the intervention studies in adolescents that showed that calcium supplementation can increase bone mass (12, 15–17). They also support the concept that continued intake of calcium may be critical for optimizing peak bone mass attainment because the gains in bone mass after supplementation were no longer significant after the postintervention period (18). This may be because of the length of the remodeling transient and because longer periods of supplementation are necessary to measure the changes in bone (23). In the current study, current calcium intake predicted only SBMC. However, milk intake during adolescence correlated with current calcium intakes, suggesting that although the current calcium intakes did not independently influence TBBMD, TBBMC, RBMD, and RBMC, it is possible that the continued intake of calcium was able to maintain the increases in these measures achieved during adolescence into adulthood.

The relation of current calcium intake to bone mass has been shown but the effect in young women remains controversial. Observational studies of women in their third decade of life, similar to the subjects in the current study, showed a relation between calcium intake and bone measures (3, 24). Calcium intake was positively correlated with the rate of change in spine BMD over a period of 1.6–4.0 y (3). In addition, the weight ratio of calcium to protein correlated with radial BMC and BMD in 24–28-y-old women (24). Supplementation with dairy products prevented spine bone loss in 30–42-y-old premenopausal women (25). In contrast to these studies, calcium intake was not correlated with BMD at the spine, femur, or radius, nor with longitu-

**TABLE 4**
Regression analysis of previous milk intakes and current calcium intakes with bone mineral measures[1]

| | Regression coefficients | | | | |
|---|---|---|---|---|---|
| | Intercept | Weight | Adolescent milk intake | Current calcium intake | Total $R^2$ |
| Total-body BMD | 0.848 ± 0.031 | 0.004 ± 0.0004 | 0.015 ± 0.006 | | 0.361 |
| Total $R^2$ | | 0.344 | 0.016 | | |
| Total-body BMC | 650 ± 117 | 27.0 ± 1.5 | 79.82 ± 24.450.0 | | 0.600 |
| Partial $R^2$ | | 0.580 | 0.020 | | |
| Spine BMD | 0.892 ± 0.063 | 0.005 ± 0.0008 | | | 0.123 |
| Partial $R^2$ | | 0.123 | | | |
| Spine BMC | 15.28 ± 3.70 | 0.455 ± 0.048 | | 0.002 ± 0.001 | 0.303 |
| Partial $R^2$ | | 0.283 | | 0.020 | |
| Femoral neck BMD | 0.792 ± 0.047 | 0.003 ± 0.0007 | | | 0.09 |
| Partial $R^2$ | | 0.09 | | | |
| Radius BMD | 0.550 ± 0.023 | 0.0017 ± 0.0003 | 0.014 ± 0.005 | | 0.153 |
| Partial $R^2$ | | 0.122 | 0.031 | | |
| Radius BMC | 0.555 ± 0.045 | 0.004 ± 0.001 | 0.022 ± 009 | | 0.180 |
| Partial $R^2$ | | 0.160 | 0.019 | | |

[1]BMD, bone mineral density; BMC, bone mineral content. All regression coefficients shown are significant, $P < 0.05$.

dinal changes in BMD of the spine and radius over a 2-y period in women aged 20–39 y (26). In the current study, it is not surprising that only current calcium intake affected the spine because the spine is predominantly trabecular bone and has a high metabolic turnover rate compared with cortical bone. In addition, the spine attains peak bone mass during the mid-20s (3, 4), and thus, it is logical that current intakes in this age range will influence the amount of bone mass at this site.

The results of the regression analyses suggest that adolescent intake and current calcium intake can have a substantial impact on the attainment of peak bone mass. For example, an individual with a weight of 62 kg who drank milk at almost every meal (level 3) during adolescence would have 6.6% greater (2563 g/2404 g) TBBMC [650 + (27 × 62) + (79.82 × 3) = 2563 g; Table 4] by the age of 18–31 y compared with an individual of the same weight who rarely drank milk (level 1) during adolescence [650 + (27 × 62) + (79.82 × 1) = 2404 g]. On the other hand, an individual of the same weight (62 kg) who has a current calcium intake of 1200 mg/d [15.28 + (0.455 × 62) + (0.002 × 1200) = 45.89 g] will have 2.6% greater (45.89 g/44.69 g) SBMC than a women of the same weight who has a daily calcium intake of 600 mg/d [15.28 + (0.455 × 62) + (0.002 × 600) = 44.69 g]. The predicted influence of calcium intakes on bone can affect the risk for osteoporosis because bone mass is inversely related to fracture risk. A shift in bone mass from the second-lowest to the lowest quartile of SBMD is estimated to increase the incidence of hip fracture/1000 person-y by ≈2.5 times (27). These increases in bone mass that increased calcium intake may cause, if maintained into adulthood, are likely to reduce the risk of fractures in later life.

In summary, this study showed the importance of milk intake in childhood and adolescence as well as current intake of calcium for optimizing attainment of peak bone mass at a variety of bone sites. Dietary calcium intakes decline from childhood to adolescence, leading to suboptimal intakes of calcium during this critical time period (28). The results of the current study suggest that although milk intake may decline from childhood to adolescence, the development of dietary habits that include the frequent intake of milk during childhood and adolescence is likely to lead to higher calcium intake in later years. Therefore, recommendations to the public should continue to emphasize increased calcium intake, perhaps most effectively achieved (in the absence of lactose intolerance) by increasing milk intake, throughout the period of peak bone mass development.

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