# Children who avoid drinking cow milk have low dietary calcium intakes and poor bone health[1–3]

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**ABSTRACT**

**Background:** Information concerning the adequacy of bone mineralization in children who customarily avoid drinking cow milk is sparse.

**Objective:** The objective was to evaluate dietary calcium intakes, anthropometric measures, and bone health in prepubertal children with a history of long-term milk avoidance.

**Design:** We recruited 50 milk avoiders (30 girls, 20 boys) aged 3–10 y by advertisement. We measured current dietary calcium intakes with a food-frequency questionnaire and body composition and bone mineral density with dual-energy X-ray absorptiometry and compared the results with those of 200 milk-drinking control children.

**Results:** The reasons for milk avoidance were intolerance (40%), bad taste (42%), and lifestyle choice (18%). Dietary calcium intakes were low (443 ± 230 mg Ca/d), and few children consumed substitute calcium-rich drinks or mineral supplements. Although 9 children (18%) were obese, the milk avoiders were shorter ($P < 0.01$), had smaller skeletons ($P < 0.01$), had a lower total-body bone mineral content ($P < 0.01$), and had lower $z$ scores ($P < 0.05$) for areal bone mineral density at the femoral neck, hip trochanter, lumbar spine, ultradistal radius, and 33% radius than did control children of the same age and sex from the same community. The $z$ scores for volumetric (size-adjusted) bone mineral density (g/cm$^3$) were $-0.72 \pm 1.17$ for the lumbar spine and $-0.72 \pm 1.35$ for the 33% radius ($P < 0.00$l). Twelve children (24%) had previously broken bones.

**Conclusions:** In growing children, long-term avoidance of cow milk is associated with small stature and poor bone health. This is a major concern that warrants further study. *Am J Clin Nutr* 2002;76:675–80.

**KEY WORDS** Dietary calcium, bone density, milk avoidance, children, obesity, fractures, cow milk allergy, New Zealand

## INTRODUCTION

Calcium is a major component of bone. During growth, an adequate dietary supply of calcium is considered to be critically important for the acquisition of strong and healthy bone (1). If children are to attain their genetically potential peak bone mass, the diet must meet the threshold of calcium needed to satisfy the needs of the skeleton (2). Accrual of good peak bone mass in youth is important for the prevention of osteoporosis in later life (3, 4).

In most Western countries, more than two-thirds of the dietary calcium intake is derived from the consumption of milk and dairy products (5, 6). Adults who consumed plenty of milk as children have a better bone density than do those who did not (7–10). Milk supplementation also augments height (11) and bone gain (12–14) in children, at least in the short term. However, some children chronically avoid drinking cow milk, either because milk consumption induces adverse symptoms (15, 16) or simply because they dislike the taste or it is a lifestyle choice. Unless these children increase their intake of other calcium-rich foods or consume mineral calcium supplements to compensate for the lack of calcium from cow milk, they could be jeopardizing their bone health. Because milk is a rich source of other important nutrients (5, 17), avoiding it could also affect general growth and bone development adversely.

Several previous studies showed low dietary calcium intakes in children who consume low amounts of milk because of milk allergies or lactose intolerance (18–20). Children in rural South African with habitually low dietary calcium intakes have lower appendicular bone mineral density (BMD) than do control children who consume more calcium (21). Furthermore, calcium supplementation increases bone density in children with habitually low calcium intakes (22, 23). However, information concerning the bone mass of children in Western societies who deliberately avoid drinking cow milk is sparse; we are aware of only 3 such studies (24–26). Limited regions of the skeleton were examined in these studies and research concentrated on children who experienced severe symptoms after the ingestion of cow milk. Stallings et al (24) showed that l8 children aged 6–12 y with lactose intolerance had lower bone density in the forearm radius than did healthy children of similar age, height, and weight. Henderson and Hayes (25) reported positive associations between bone densities of the hip and spine and current calcium intakes in 55 children aged 5–14 y who had previously shown positive serum antibodies to cow-milk protein. Finally, spinal bone density was strongly correlated with current calcium intake in 30 children aged 2–7 y with very low calcium intakes who eschewed dairy foods (26).

No previous studies of either calcium intake or bone health have been undertaken in New Zealand children who habitually avoid drinking cow milk. The present study was undertaken to assess the current dietary calcium intake, bone mineral content, bone size, and BMD in the whole skeleton and in specific regions in 50 children with a history of chronic milk avoidance.

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**TABLE 1**
Characteristics of the milk avoiders[1]

| | Girls ($n$ = 30) | Boys ($n$ = 20) |
|---|---|---|
| Age (y) | 5.9 ± 1.9 (3.0–10.2) | 6.4 ± 2.3 (3.0–10.9) |
| Height (cm) | 113.2 ± 13.4 (88–145) | 119.0 ± 17.7 (95–151) |
| Weight (kg) | 23.4 ± 9.0 (12.3–51.3) | 25.0 ± 10.2 (13.5–49.8) |
| BMI (kg/m$^2$) | 17.6 ± 2.8 (14.2–24.8) | 17.0 ± 2.4 (14.6–25.7) |
| Percentage body fat (%) | 20.6 ± 8.9 (10.4–44.7) | 16.8 ± 6.6 (9.2–34.2) |
| Fat mass (kg) | 5.3 ± 5.0 (1.3–22.2) | 4.5 ± 3.8 (1.5–16.7 |
| Lean mass (kg) | 16.4 ± 4.2 (9.1–26.5) | 18.6 ± 6.4 (10.5–31.8) |
| Total-body bone mineral content (g) | 705 ± 261 (295–1454) | 834 ± 394 (349–1680) |
| Total-body bone area (cm$^2$) | 869 ± 256 (418–1567) | 976 ± 364 (528–1789) |
| Total-body aBMD (g/cm$^2$) | 0.80 ± 0.06 (0.71–0.93) | 0.83 ± 0.09 (0.66–0.99) |
| Total-body calcium (g) | 268 ± 99 (112–553) | 317 ± 150 (133–639) |
| Femoral neck aBMD (g/cm$^2$) | 0.56 ± 0.17 (0.21–0.84) | 0.67 ± 0.18 (0.39–0.90) |
| Trochanteric aBMD (g/cm$^2$) | 0.55 ± 0.11 (0.19–0.72) | 0.62 ± 0.13 (0.46–0.83) |
| L2–L4 aBMD (g/cm$^2$) | 0.62 ± 0.10 (0.42–0.87) | 0.62 ± 0.13 (0.44–0.82) |
| Ultradistal radius aBMD (g/cm$^2$) | 0.22 ± 0.04 (0.14–0.32) | 0.23 ± 0.04 (0.15–0.31) |
| 33% Radius aBMD (g/cm$^2$) | 0.36 ± 0.07 (0.23–0.56) | 0.37 ± 0.09 (0.24–0.54) |
| L2–L4 BMAD (g/cm$^3$) | 0.14 ± 0.02 (0.11–0.17) | 0.09 ± 0.02 (0.06–0.13) |
| 33% Radius BMAD (g/cm$^3$) | 0.18 ± 0.04 (0.12–0.27) | 0.13 ± 0.02 (0.10–0.16) |
| Dietary calcium intake (mg/d) | 420 ± 228 (75–849) | 478 ± 234 (75–999) |

[1] $\bar{x}$ ± SD; range in parentheses. aBMD, areal bone mineral density; BMAD, bone mineral apparent density.

## SUBJECTS AND METHODS

### Recruitment of study participants

Advertisements to participate in a study of general nutrition and bone health were placed in local newspapers, play centers, schools, well-baby clinics, supermarkets, health food shops, libraries, and sporting venues, seeking volunteers of either sex aged 3–10 y who had a history of avoiding the consumption of cow milk for >4 mo at some stage in their lives. Children from the Dunedin area of New Zealand who avoided cow milk for any reason were eligible, regardless of whether they had made any attempts to increase their dietary calcium intakes from other sources. However, children with gait disorders, current bone fractures, or medical diagnoses affecting bone (eg, diabetes or malabsorptive syndromes) were excluded from entry to the study. The study protocol was approved by the ethics committee of our local hospital, and written, informed parental consent was obtained for every child participant.

### Protocol

Each child came with a parent to the Bone Research Laboratory for a 90-min appointment. Information about symptoms related to milk consumption, history of milk avoidance, use of mineral supplements or calcium-rich food substitutes, medical history, pubertal development, and use of medications was collected by questionnaire. Habitual calcium intakes over the preceding year were evaluated with the use of a food-frequency questionnaire that was administered to each child and parent by the same interviewer. This questionnaire was previously validated with 4-d diet records in 67 children of similar age (27). The weight (with an electronic balance) and height (with a Harpenden stadiometer; Holtain LTD, United Kingdom) of each child were measured while they wore no shoes and light clothing. Body mass index (BMI) was calculated (weight in kilograms divided by height squared in meters), and body composition (lean mass, fat mass, and percentage body fat) was estimated with the use of dual-energy X-ray absorptiometry (DXA) of the total body, left hip, lumbar spine, and nondominant forearm; regional areal BMD (aBMD; g/cm$^2$) was estimated with the use of a Lunar DPX-L scanner (Lunar Corp, Madison, WI). This method, including its precision, was described previously (28). The scans were analyzed with Lunar software packages 1.35 (total body, hip, ultradistal radius, and 33% radius) and 1.5h (pediatric spine package). Volumetric bone mineral apparent density (BMAD; g/cm$^3$) was calculated at the 33% radius site as bone mineral content divided by (area)$^2$ (29) and in the lumbar spine L2–L4 vertebrae as bone mineral content divided by (area)$^{1.5}$ (30). These BMAD measures are considered more robust than the aBMD measures because they are less influenced by bone size (31).

### Control population

Our control children (100 white girls and 100 white boys living in the same town as the milk avoiders), who had no history of bone fracture or bone disease, were recruited over the previous 6 y (32, 33). Their anthropometric and bone density measurements were performed in the same research laboratory by using the same methods used for the milk avoiders, and their results were used to calculate the sex-specific, age-adjusted $z$ scores for the anthropometric and bone variables. The mean (± SD) dietary calcium intakes of these milk-drinking control subjects were as follows: 1179 ± 332 mg/d in the girls (32) and 1278 ± 618 mg/d in the boys (33).

### Statistical analysis

The statistical analysis was performed by using SAS (release 6.12; SAS Institute, Cary, NC), and the results are given as means ± SDs. Both aBMD and volumetric BMAD are expressed as $z$ scores for age. A $z$ test was used to establish whether $z$ scores in the study population differed from those in the reference population. Pearson's correlation coefficients were determined to assess associations of current dietary calcium intake with aBMD and volumetric BMAD measurements.

## RESULTS

The characteristics (raw data) of the 50 milk avoiders are shown in **Table 1**. All of the children were white and in good health. However, on the basis of their BMIs (34), 15 of the children were overweight (> 85th percentile), 9 (7 girls, 2 boys) of whom were obese (> 95th percentile). Body fat measurements confirmed high

**TABLE 2**
Features of the milk avoiders who did or did not report symptoms after the ingestion of cow milk

| | Symptoms ($n$ = 25) | No symptoms ($n$ = 25) |
|---|---|---|
| | *n* | |
| Reasons for avoidance | | |
| Milk intolerance | 20 | 0 |
| Bad taste | 3 | 18 |
| Lifestyle choice[1] | 2 | 7 |
| Subjects whose family member avoided cow milk consumption | 20 | 19 |
| Consulted a health professional[2] | | |
| Yes | 21 | 7 |
| No | 4 | 18 |

[1] The family consumed soymilks or goat milk rather than cow milk.
[2] General practitioner, dietitian, nurse, or pediatrician.

**TABLE 3**
Age-adjusted *z* scores for anthropometric and bone variables for the 50 milk avoiders[1]

| | Value | $P$[2] |
|---|---|---|
| Height (cm) | −0.65 ± 1.42 (−4.13–2.87) | <0.01 |
| Weight (kg) | 0.04 ± 1.15 (−1.92–4.02) | NS |
| BMI (kg/m$^2$) | 0.49 ± 0.89 (−0.92–3.96) | <0.001 |
| Fat mass (kg) | 0.12 ± 1.03 (−1.53–3.04) | NS |
| Lean mass (kg) | −0.08 ± 0.98 (−2.37–1.69) | NS |
| Total-body bone mineral content (g) | −0.45 ± 1.16 (−3.19–2.85) | <0.01 |
| Total-body bone area (cm$^2$) | −0.56 ± 1.34 (−4.16–2.91) | <0.01 |
| Total-body aBMD (g/cm$^2$) | 0.13 ± 0.77 (−1.39–2.19) | NS |
| Femoral neck aBMD (g/cm$^2$) | −1.11 ± 2.27 (−8.38–2.15) | <0.001 |
| Trochanteric aBMD (g/cm$^2$) | −0.47 ± 1.58 (−7.89–2.30) | <0.05 |
| L2–L4 aBMD (g/cm$^2$) | −0.45 ± 1.05 (−3.06–1.36) | <0.01 |
| Ultradistal radius aBMD (g/cm$^2$) | −0.31 ± 0.99 (−4.14–1.64) | <0.05 |
| 33% Radius aBMD (g/cm$^2$) | −0.74 ± 1.40 (−3.60–2.56) | <0.01 |
| L2–L4 BMAD (g/cm$^3$) | −0.72 ± 1.17 (−3.82–1.13) | <0.001 |
| 33% Radius BMAD (g/cm$^3$) | −0.72 ± 1.35 (−3.97–2.29) | <0.001 |

[1] $\bar{x}$ ± SD; range in parentheses. aBMD, areal bone mineral density; BMAD, bone mineral apparent density.
[2] Difference between the distribution of *z* scores obtained in the milk avoiders and that in the healthy population.

adiposity in all of the overweight children. Only one child had a low BMI (between the 5th and the 10th percentile). Twenty-three children had a history of allergy, 6 of eczema, 4 of otitis media, and 17 of asthma. Sixteen children used inhalers for asthma, 3 took antihistamines, 1 took an antidepressant (fluoxetine), and 1 was taking medication (paracetamol) regularly for headache.

Most of the children (94%) had been breast-fed, many for a considerable amount of time: 84% for >6 mo, 60% for >1 y, and 18% for >2 y. The children had started to avoid cow milk at 1.2 ± 1.5 y of age (range: 0–6.3 y) and had avoided cow milk for 73% of their lives (4.5 ± 2.5 y; range: 0.3–10.4 y). Most children (60%) stated that they avoided cow milk simply because they disliked the taste or because their family chose to consume soymilk or goat milk instead (**Table 2**). Although only one-half of the study population had ever experienced symptoms after the consumption of cow milk, a high proportion of the children (78%) had a family member who also avoided cow milk: 32 children had at least one parent and 24 children had at least one sibling with this dietary pattern. The 25 children who reported previous symptoms of cow-milk allergy had gastrointestinal symptoms ($n$ = 16), rhinitis ($n$ = 9), cough or wheeze or respiratory symptoms ($n$ = 6), general malaise ($n$ = 2), and headaches ($n$ = 1). Although most of the parents (97%) rated cow milk as an important nutritional food for growing children, a surprisingly high proportion (44%) of the whole study population, particularly the nonsymptomatic group, had never sought advice from health professionals regarding the possible adverse effects of long-term milk avoidance (Table 2). However, 76% of the parents had tried to reintroduce cow milk into the diets of their children.

The milk avoiders had a low calcium intake (Table1), although most children consumed small amounts of some dairy products, such as cheese, yogurt, and ice cream. Six children took small amounts of elemental calcium ($\bar{x}$: 64 mg/d; maximum: 170 mg/d). In New Zealand the daily recommended nutrient intakes (RNIs) for calcium (35) are 700, 800, and 900 mg for girls aged 3, 4–7, and 8–10 y, respectively, and are 700 and 800 mg for boys aged 3 and 4–10 y, respectively. Only 4 of the milk avoiders (8%) had intakes that met these RNIs, whereas 57% consumed less than two-thirds and 22% less than one-third of the RNI for this mineral. Eight subjects who had a history of long-term avoidance of cow milk had recently started to drink small amounts of cow milk; they had higher calcium intakes (654 ± 194 mg/d) than did the 42 children who were currently avoiding cow milk (403 ± 216 mg/d) ($P < 0.004$). Although 15 of the 42 children who avoided cow milk drank some soymilk or goat milk, their calcium intakes were not significantly higher than those of the 27 children who took no substitute calcium-containing beverages (430 ± 211 compared with 388 ± 221 mg/d).

The milk avoiders were significantly shorter and had higher BMIs than did the control children (**Table 3**). Compared with the control children, the milk avoiders also had smaller bones, a significantly lower total-body bone area, a lower total-body bone mineral content, and lower *z* scores for aBMD at all regional sites. Reductions in regional density occurred in both sexes (**Figure 1**). The *z* scores for total-body bone mineral content ($r = 0.29$, $P < 0.036$) and total-body aBMD (**Figure 2**; $r = 0.38$, $P < 0.006$) were each positively correlated with calcium intake. Dietary calcium intakes also correlated with the *z* scores for aBMD at the hip trochanter ($r = 0.30$, $P < 0.039$) and with volumetric BMAD *z* scores ($r = 0.39$, $P < 0.005$) at the 33% radius (**Figure 3**) but not with aBMD at sites rich in trabecular bone (ultradistal radius and lumbar spine). The mean dietary calcium intakes and BMD values of children with and without symptoms to cow milk did not differ significantly (data not shown).

A high proportion of our sample had already experienced broken bones. Twelve subjects, of whom 6 were overweight, reported 17 previous fractures. Nine children had sustained a single fracture, 2 children reported 2 fractures, and 1 child had sustained 4 fractures on separate occasions. Ten fractures of the distal forearm were reported, for an annual incidence of 3.5% rather than the expected 1.0% (36).

## DISCUSSION

This study is the first to evaluate skeletal size and to measure aBMD in the whole skeleton and at specific regional skeletal sites with DXA in a sample of healthy children who avoided the consumption of cow milk. Our results strongly support the view that children with a history of long-term avoidance of cow milk have very low dietary calcium intakes and poor bone health in comparison with milk-drinking children. We also confirmed earlier observations (24) that suggest that children who do not drink milk

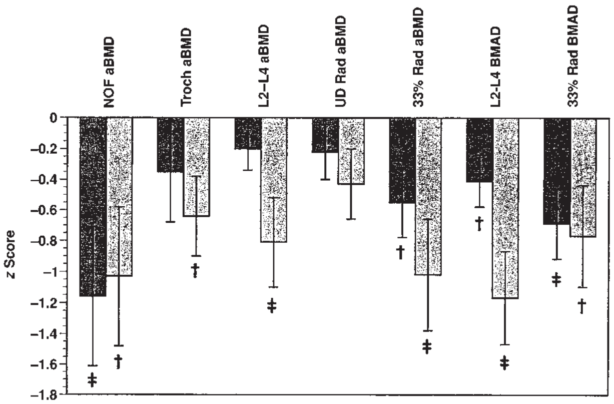


**FIGURE 1.** Mean (± SEM) *z* scores for areal bone mineral density (aBMD; g/cm$^2$) or volumetric bone mineral apparent density (BMAD; g/cm$^3$) in the neck of femur (NOF), trochanter (Troch), L2–L4 vertebrae, ultradistal radius (UD Rad), and 33% radius of girls (■; $n$ = 30) and boys (■; $n$ = 20) who avoided cow-milk consumption. [†,‡]Significantly different from the milk-drinking control children: $^{†}P < 0.05$, $^{‡}P < 0.01$ (*z* test).

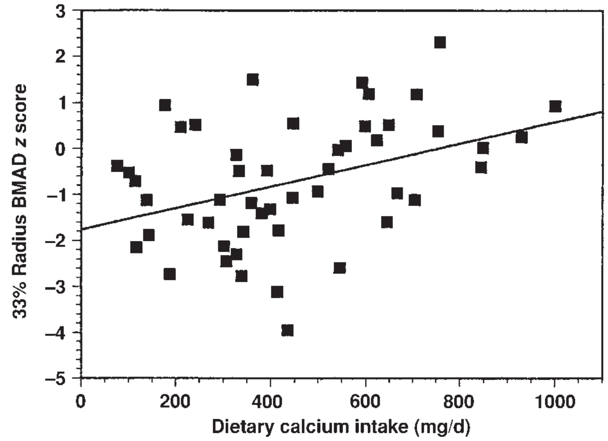


**FIGURE 3.** Relation between current dietary intakes of calcium and *z* scores for volumetric bone mineral apparent density (BMAD; g/cm$^3$) at the 33% radius site in 50 children who avoided cow-milk consumption ($r$ = 0.39, $P < 0.005$).

have a shorter stature than do those who consume milk regularly. An additional novel finding was that 18% of our study population was obese.

We found that milk avoiders had smaller skeletons, significantly lower bone area and bone mineral contents, and lower volumetric BMD values than did the fracture-free control children of the same age and sex drawn from the same community. Although the low aBMD values in the milk avoiders could have been an artifact of their small bone size (31), low volumetric bone density is not a consequence of having a small bone size. Thus, the low volumetric BMAD *z* scores in both the spine (rich in trabecular bone) and in the 33% radius (predominantly cortical bone) indicated that the milk avoiders had less mineral in a given volume of bone than did the milk-drinking control children. Because bones with a low density break with less force than do bones with a high density, a low density could increase the susceptibility of bones to fracture (28, 32, 33). The milk avoiders in the present study had sustained a high number of bone fractures, supporting the proposition that children who habitually avoid the consumption of cow milk who have low aBMD values are vulnerable to fracture. Unless this situation changes during growth, it is possible that these children may reach adulthood with a low peak bone mass. This would make them more vulnerable to osteoporotic fractures later in life, when bone mass decreases as an effect of menopause or aging, than are children with denser, stronger bones.

When the dietary supply of calcium falls below the threshold needed to satisfy the calcium needs of the body long term, the skeleton is likely to be affected adversely (1, 2). We found moderate evidence at some skeletal sites of an association between current calcium intakes and the *z* scores for aBMD and volumetric BMAD. This association suggests some relation between low calcium intake and low BMD but does not imply causality. However, children who had low dietary calcium intakes tended to have lower aBMD values in the total body and lower volumetric BMAD values at the 33% radius than did the children who consumed higher of amounts of dietary calcium. Presumably, these associations were found because children with low calcium intakes at the time of the study also had low calcium intakes for many years previously, during the crucial years of bone growth. We recognize that the assessment of current calcium intakes provides only a snapshot of lifelong intakes, whereas bone mineral measurements reflect the sum of long-term nutrition. Because most of our children reported prolonged milk avoidance, and milk is a rich source of many nutrients, it is possible that the associations we observed between bone density and calcium related to low milk consumption, not merely to a lack of calcium.

Previous studies of bone health in children who avoid the consumption of cow milk were restricted to evaluations of children with symptoms of intolerance to ingestion of milk. By contrast, a high proportion of our study population avoided milk merely because they disliked its taste or because their families chose not to offer it to them. Only one-half of the milk avoiders reported that they had ever experienced abdominal pain, bloating, vomiting, diarrhea, nasal congestion, or skin rashes after consuming cow milk. Because the dietary calcium intakes and BMD measurements of the children without symptoms did not differ from those

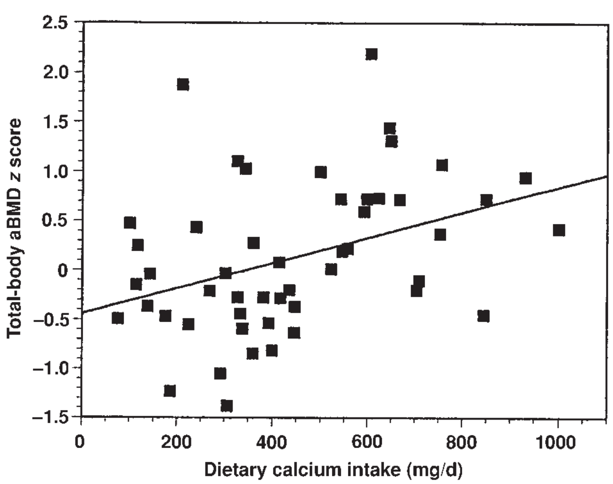


**FIGURE 2.** Relation between current dietary intakes of calcium and *z* scores for total-body areal bone mineral density (aBMD; g/cm$^2$) in 50 children who avoided cow-milk consumption ($r$ = 0.38, $P < 0.006$).

of the children with symptoms, the findings of our study strongly suggest that it is chronic avoidance of milk, rather than health problems associated with milk allergy or intolerance, that is responsible for poor bone development.

The eating behavior of children is strongly influenced by parental behavior (37). Children whose mothers consume milk regularly drink more milk than do children whose mothers do not drink milk regularly (38). Because a high proportion of our subjects (64%) had at least one parent who disliked or avoided milk, it seems likely that parental milk avoidance was an important factor contributing to this dietary habit. Clearly, children living in households that do not have cow milk readily available will drink milk less often than will children living in households in which cow milk is readily available. Although most parents perceived milk to be an important food source of protein, vitamins, and minerals, few had consulted health professionals regarding the possible long-term adverse consequences of milk avoidance or had attempted to provide their children appropriate dietary substitutes.

The past avoiders of cow milk who were drinking some cow milk at the time of the study had higher calcium intakes than did those who were not drinking cow milk at the time of the study. However, their intakes remained lower than was desirable. This finding may reflect the difficulties known to be associated with altering early childhood patterns of food intake. The low calcium intakes of the study children are a concern because these children will need to increase their dietary calcium intakes considerably to correct their bone deficits and satisfy the greatly increasing mineral demands of the growing skeleton, particularly at puberty. Our longitudinal DXA studies of fracture-free children conducted between 1996 and 2002 (A Goulding, unpublished observations) showed that, although prepubertal children aged 3–10 y retain an average of ≈120 mg Ca/d in the growing skeleton, the demand may peak to > 600 mg Ca/d in puberty. The dietary intakes of the milk avoiders in the present study would not meet the high calcium demands of pubertal growth.

Unfortunately, we had no information on the heights of the parents of the milk avoiders in the present study. Thus, we cannot definitively attribute short stature to nutritional inadequacies associated with milk avoidance. However, milk is a major source of minerals, vitamins, energy, and protein at this age, and decreased height velocity is often seen when nutrition is inadequate (39). Bonjour et al (12) found that height gain followed dairy supplementation in prepubertal girls with initially low calcium intakes. Our finding of short stature in children consuming milk-elimination diets or with milk allergy or lactose intolerance is compatible with the findings of others (24, 40, 41). Milk usually provides 25% of the dietary protein of young children in Western societies; therefore, the short stature of children who avoid milk could be due to inadequate dietary protein intakes. Milk supplementation has also been shown to elevate blood insulin-like growth factor I concentrations (13, 42), and insulin-like growth factor I is considered important for bone mineral accrual, particularly on periosteal surfaces (43). Thus, it is possible that milk avoiders have lower insulin-like growth factor I concentrations to stimulate bone growth than do milk drinkers.

The high proportion of overweight and obese children in the present study was an unexpected finding, particularly because many of the children had been breast-fed for prolonged periods (44). Because we did not measure energy balance in our study, we cannot say whether the high adiposity of these children was due to excessive energy intakes or to inadequate energy expenditure. It could be that the milk avoiders were drinking more high-energy substitute fluids, such as fruit juice or carbonated drinks. Short stature and obesity have been reported in children who consume excessive amount of fruit juice (45), although not always (46). Alternatively, the milk avoiders in the present study may have been less physically active than the control subjects. Low activity would have affected bone growth adversely because intermittent weight-bearing exercise is a critically important stimulus to osteogenesis in prepubertal children (47–50). Another possible mechanism contributing to the high adiposity we observed in the milk avoiders was that their high body weights were linked to their low calcium intakes. Recent studies suggest that low dietary calcium intakes can stimulate lipogenesis and inhibit lipolysis simultaneously, resulting in the accumulation of body fat (51–54).

In summary, our study of young male and female prepubertal children with a long history of avoiding cow-milk consumption has identified major problems in bone health (eg, small bones, low aBMD and volumetric BMAD, and a high prevalence of bone fractures) that many health professionals and members of the general public appear to be unaware of. Short stature and high adiposity were other health concerns. Ideally, a full dietary assessment of children who avoid milk consumption seems warranted to help identify possible nutritional deficiencies or excesses. Future studies of bone health in larger populations of children who avoid the consumption of cow milk are desirable to confirm our findings and to determine whether the problems associated with this dietary pattern resolve as the children grow (4). In the interim it seems prudent to advise parents of all children who do not drink cow milk that they should seek professional nutritional advice to help optimize their children's bone health.

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