29 The Likely Importance of Specific Dairy Foods in Relation to Bone Health: Current Knowledge and Future Challenges

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Abstract

Osteoporosis is a major public health problem affecting over 200 million people worldwide. The 2010 dietary guidelines for Americans recommend consuming 3 cups/day of fat-free or low-fat dairy products for adults. Although individual nutrients usually found in dairy products may be beneficial for bone health, few studies have directly compared specific types of dairy foods. Yet it has been suggested that dairy foods are not equivalent vehicles of calcium due to their different nutrient profile. While studies of milk intake and bone mineral density (BMD) are plentiful and mostly positive, the evidence for hip fracture risk reduction remains weak. Studies on yogurt intake and bone health have been very few but promising though the role of probiotics in yogurt on bone is unclear. It is unclear how other dairy foods may relate to bone health. Few studies that have examined cheese intake have focused either on intake of total cheese or a specific low-fat variety. High-fat/high-sugar dairy foods like cream and ice cream have low nutrient density and are widely consumed, yet very little is known about their impact on the skeleton. The additive and synergistic role of sodium and saturated fats along with other bone-specific nutrients (e.g., calcium, vitamin D, phosphorus, protein) in cream and cheese is complicated and needs further clarification. Future studies should (i) aim to resolve the disparate findings from BMD studies versus fracture studies on milk intake, (ii) clarify the role of probiotics in calcium absorption and bone health, (iii) focus on the skeletal effects of low-fat cheese and the influence of

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sodium content of the different cheeses, and (iv) focus on dairy food products instead of single nutrients within dairy while at the same time considering nutrient profiles of specific dairy foods. Overall, the studies that are highlighted in this chapter suggest a significant role for dairy intake in maintaining bone health.

Keywords
Dairy • Milk • Yogurt • Cheese • Cream • Bone mineral density • Hip fracture • Dietary intake • Bone health

Introduction

Osteoporosis is a major public health problem affecting more than 200 million people worldwide [1]. While many risk factors have been described, dietary factors represent an important but less investigated area of research for bone health. The 2010 dietary guidelines for Americans recommend consuming three cups per day of fat-free or low-fat milk and milk products for adults [2]. Yet dairy foods are a complex source of essential nutrients, including protein, carbohydrates, fatty acids, calcium, phosphorus, potassium, and magnesium, and in the USA are often fortified with vitamin D. It has been suggested that the health effects of dairy foods may be due to more than a single nutrient, and in fact, the effects of dairy foods may be greater than the sum of their parts. A review by Heaney [3] and a report by the US Dietary Guidelines advisory committee [4] both reported that 25 out of 32 observational studies and 11 out of 11 randomized controlled trials showed a significantly positive association between dairy food intake and bone mineral density (BMD) or bone mineral content (BMC).

In one observational study using the Framingham Offspring cohort, most dairy intake (defined as the sum of milk, yogurt and cheese intake) was positively associated with hip and spine BMD [5]. In two randomized controlled trials, high dairy intake was protective against bone loss at the total hip [6] and the vertebrae [7]. Individual nutrients usually found in dairy products, such as calcium and vitamin D [8], protein [9, 10], and potassium [11], have been shown to be beneficial for bone health, while high intakes of sodium [12] may have a negative impact. However, few studies have directly compared different types of dairy foods even though it has been suggested that dairy foods are not equivalent vehicles of calcium due to their different protein, sodium, potassium, and vitamin A contents [13]. As the nutrient profile changes a great deal with the different types of dairy foods, consequently not all dairy foods should be expected to have a similar impact on bone health. For example, a diet rich in milk or yogurt rather than cheese or cream can increase the intakes of potassium, vitamin A, and vitamin D and decrease intakes of sodium, cholesterol, and saturated fatty acids. Thus, Weinsier and Krumdieck raised an important question in their (2000) review paper [13] as to whether the dairy options in the US Dietary Guidelines are nutritionally equivalent and exchangeable for optimal bone health. Based on the nutrient profiles of dairy foods, it can be predicted that milk (which has the largest calcium to sodium ratio of 2.4) and yogurt may be beneficial for the skeleton, whereas certain cheeses, which have high sodium and polyphosphate, may be less advantageous [13]. Due to its low nutrient density, cream may actually be disadvantageous to bone health. Furthermore, calcium from yogurt has higher bioavailability than from milk due to its acidic pH, which ionizes the calcium, facilitating absorption [14]. Whereas the manufacture of fresh, aged, and processed cheeses results in products that differ markedly in their content of dairy-specific nutrients compared to milk [13]. In light of these factors, it is important to examine the impact of individual dairy foods upon bone health. Of the dairy foods, milk remains the most studied; far less is known about the asso-

ciations of other dairy foods, such as yogurt, cheese, and cream, with bone health. The objective of this book chapter is to highlight findings from previous studies on this topic to underscore our current understanding and emphasize the importance of examining the individual dairy foods and their role in skeletal health.

Milk Intake and Bone Health

Evidence from Observational Studies

Several cross-sectional studies have reported a positive link between childhood milk consumption and bone density later in life [15–19]. Evidence for a beneficial role of milk intake on osteoporotic fracture is less convincing [18, 20–22]. A cross-sectional study of women (aged 44–74 years) found consistent associations between self-reported milk consumption before the age of 25 years and higher bone mineral density (BMD) of the total hip, femoral neck, trochanter, intertrochanter ($P<0.05$ each), and Ward's triangle ($P<0.005$) [15]. Results from 581 older white women (mean age, 71 years) in the Rancho Bernardo Study showed that regular milk consumption in youth was associated with higher BMD values at cortical and trabecular sites [23]. In 2,479 men and women (mean age, 54.9 ± 9.6 years) from the Framingham Offspring Study, participants in the highest quartile of current milk intake tended to have significantly higher BMD of the femoral neck (P trend = 0.08) and trochanter (P trend = 0.05) compared to participants in the lowest quartile of milk intake. No significant associations were observed for lumbar spine BMD (P trend = 0.29). In this study, after adjusting for other dairy foods, milk intake remained weakly but positively associated with femoral neck BMD ($P=0.06$) [5]. In the third National Health and Nutrition Examination Survey, women aged 20–49 years who consumed <1 serving of milk per week during childhood (ages 5–12 years) were found to have 5.6 % less bone mineral content (BMC) than those who consumed >1 serving per day. Similarly, women who consumed <1 serving of milk per week during adolescence were found to have ~3 % lower hip BMC and BMD ($P<0.02$) than those who consumed >1 serving per day [18]. In the same study, women aged 50 years or older with low milk intake during childhood were found to have twice the risk of lifetime fracture [OR, 2.02 (95 % CI; 1.13, 3.59), $P<0.05$] [18]. On the other hand, a 12-year prospective study of 77,761 women (aged 34–59 years) from the Nurses' Health Study found no evidence that higher adult milk intake (≥2 glasses of milk per day versus ≤1 glass per week) reduced incidence of hip fracture [RR, 1.45 (95 % CI; 0.87–2.43)] or forearm fracture [RR, 1.05 (95 % CI; 0.88–1.25)] [22]. An 18-year prospective analysis in 72,337 postmenopausal women from the same study also showed no association between milk intake and hip fracture risk (RR for ≥1.5 glasses of milk per day versus ≤1 glass per day, 0.83; 95 % CI; 0.61–1.10) [21]. With higher daily intakes of (2.5 glasses) milk, there was still no evidence of a protective effect (RR = 0.86; 95 % CI; 0.63, 1.18) [21]. Furthermore, a (2011) meta-analysis of milk consumption and hip fracture found no overall association [Pooled RR for each additional glass of milk per day for men, 0.91 (95 % CI; 0.8–1.01) and for women, 0.99 (95 % CI; 0.96–1.02), Q test $P=0.37$] [20].

Evidence from Randomized Controlled Trials

A 2-year randomized trial of fortified milk supplementation in older men (mean age, 61.9 ± 7.7 years) showed that the net beneficial effect of fortified milk supplementation on BMD persisted at the femoral neck and ultradistal radius at the end of the intervention (1.8 and 1.5 %, respectively; $P<0.01$ for both) and was sustained at 18-month follow-up ($P<0.05$ for both), during which time no fortified milk was provided. However, no lasting benefits were observed at the lumbar spine [24]. In another randomized controlled trial of 240 healthy men and women (aged 55–85 years), who typically consumed fewer than 1.5 servings of dairy a day, increasing intake to 3 servings of milk per day for 12 weeks decreased bone resorption, with a serum parathyroid hormone decrease of 9 % and a decrease in urinary excretion of N-telopeptide of 13 % [25]. In a prospective crossover trial of 16 weeks, 30 healthy postmenopausal women aged

59.3±3.3 years were provided a 600 mg calcium diet and randomized to receive either 500 ml semi-skimmed milk (containing 600 mg calcium and no vitamin D, thus providing a total of 1,200 mg calcium) or no milk. The authors concluded that a 6-week period of milk supplementation induced a decrease in several biochemical variables compatible with diminished bone turnover mediated by reduction in parathyroid hormone secretion [26]. Similar results have been reported from other randomized controlled trials, including postmenopausal women from South Australia [27], China [28], and Chinese women in Malaysia [29].

While studies of milk intake and BMD are plentiful and mostly positive, the evidence for hip fracture risk reduction remains weak. Results from two of the largest prospective cohort studies to date have shown no association between dairy intake and the risk of hip fracture [20, 22]. As noted by Bischoff-Ferrari et al., it is quite possible that adequate vitamin D exposure is required for a benefit of milk on hip fracture prevention [20], which may explain the overall null associations in their study. This may also explain null findings from the Nurses' Health Study, where vitamin D from foods and multivitamin supplements was 448 IU/day in the high milk intake group (≥2 glasses of milk/day). Similarly, in the follow-up study, mean dietary vitamin D intake from foods alone was 5 μg/day (or 200 IU/day) and 65.8 % of the women examined had total vitamin D levels <8.99 μg/day (or 359.6 IU/day) [21].

Yogurt Intake and Bone Health

Evidence from Observational Studies

In 2,479 men and women (mean age, 54.9±1.6; range 26–85) from the Framingham Offspring Study, participants with high yogurt intake (>4 servings per week) had higher BMD at the trochanter (P trend=0.05) compared to those with no intake, while no significant associations were observed for other bone sites (P range, 0.27–0.32) [5]. Even when intakes of milk, yogurt, cheese, and cream were simultaneously included in the final model, high yogurt intake (>4 servings per week) remained positively associated with trochanteric BMD (P=0.04), and statistically borderline associations were observed with femoral neck BMD (P=0.09) compared to no yogurt intake.

Evidence from Randomized Controlled Trials

An intervention study by Heaney et al., with 29 postmenopausal women (mean age, 61±4.3 years) not taking calcium supplements and with dietary calcium intake of <600 mg/day, showed that 3 servings of yogurt (versus 3 servings of jellied fruit snack) led to 22 % lower urinary excretion of N-telopeptide (P<0.03), a marker of bone resorption [30].

Yogurt is an important source of bone-specific nutrients, is low in sodium, and has high satiety factor. Yogurt is a good source of probiotics; consequently, yogurt is better tolerated by people who avoid dairy products due to lactose intolerance. Whether these probiotics also affect the absorption of bone-specific nutrients such as calcium is yet unknown. Studies on yogurt intake and bone health have been very few but promising.

Cheese Intake and Bone Health

Evidence from Observational Studies

In men and women from the Framingham Offspring Study (mean age, 54.9±1.6), no significant associations were observed for total cheese intake with BMD at the hip or spine [5].

Evidence from Randomized Controlled Trials

Two controlled trials were conducted by Bonjour et al. [31, 32] in France that proposed skimmed-milk soft cheese as an effective dietary intervention against bone loss. In a randomized controlled trial, 71 healthy postmenopausal women (mean age, 56.6±3.9 years) with low calcium and vitamin D intakes were randomized to consume two daily servings of skimmed-milk, soft plain cheese (2×100 g) for 6 weeks (n=36 intervention; 35

placebo controls). The vitamin D and calcium-fortified cheese product provided 661 kJ of energy, 2.5 μg vitamin D, 400 mg calcium, and 13.8 g protein per day. At the end of the intervention, the decrease in TRAP 5b (tartrate-resistant acid phosphatase, isoform 5b, a bone resorption biomarker) and the increase in insulin-like growth factor-I (IGF-I, serum bone anabolic factor) were greater in the treated than in the placebo group ($P<0.02$). The changes in the resorption marker, serum carboxy-terminal cross-linked telopeptide of type I collagen, did not differ significantly between the two groups [32]. The results of this trial were consistent with the results of a previous trial by the same group that used a crossover controlled study design in older institutionalized women (mean age, 87.2 ± 6.1 years) with low vitamin D status and calcium intake <700 mg/day [31, 33].

Several have speculated that intake of hard cheeses and processed cheese products are less advantageous to bone and that cottage cheese would also be disadvantageous [13]. A possible explanation for this is that the manufacture of cheese increases its sodium content, particularly processed cheese products and the acid-cured cheeses such as cottage cheese [34]. Thus, while the recommended 2–3 dairy servings taken as milk would provide ~315 mg Na, a comparable intake of calcium from American cheese would increase the sodium intake to ~2,500 mg and if consumed as cottage cheese would increase the sodium intake to ~5,000 mg [13]. However, few studies have examined the association of cheese intake with bone health, and these studies either examined total cheese intake or focused on a specific low-fat variety. Future studies should focus on the skeletal effects of low-fat cheese and the influence of sodium content of the different cheeses.

Cream Intake and Bone Health

Evidence from Observational Studies

In the Framingham Offspring Study, no significant associations were observed for dietary cream intake (defined as the sum of intake of cream, ice cream, sour cream, and cream cheese; *P* trend range, 0.39–0.42) and BMD at the hip or spine. However, after adjustment for other dairy foods such as milk, yogurt, and cheese, cream intake tended to be negatively associated with femoral neck BMD (β, –0.00062; SE, 0.0004; *P*, 0.08) [5].

Evidence from Randomized Controlled Trials

In a randomized controlled trial, 80 women (ages 20–39 years with calcium intake <750 mg/day) were randomized to consume lower saturated fat/sugar ice cream containing 96, 244, 459, or 676 mg calcium daily for 28 days. This study concluded that daily consumption of this low fat/sugar and calcium-fortified ice cream by premenopausal women may significantly reduce levels of serum carboxy-terminal collagen cross-links (CTX, a bone resorption marker), without stimulating weight gain [35].

Dairy foods like cream, ice cream, and sour cream are usually high in saturated fat or sugar and have low nutrient density. These dairy foods are widely consumed yet very little is known about their impact on the skeleton.

Conclusion

Although the evidence for a positive association between milk intake and BMD is strong and that of yogurt intake looks promising, it is unclear how other dairy foods may be related to bone health. Recent studies have highlighted the important role of various macro- and micronutrients as well as that of milk basic protein in bone health [36, 37]. However, the additive and synergistic role of sodium and saturated fats along with other bone-specific nutrients (e.g., calcium, vitamin D, phosphorus, and protein) in dairy foods such as cream and cheese is complicated and needs further clarification. There is a clear dearth of studies on specific dairy foods and hip fractures in older adults, and thus, the evidence for hip fracture remains weak. This highlights the need for future studies to resolve the disparate findings from BMD studies versus fracture studies. Single nutrient studies cannot account for synergistic interaction between nutrients. Therefore, future studies should

focus on dairy food products instead of single nutrients within dairy. At the same time, it is vital to consider nutrient profiles of specific dairy foods while investigating their associations with bone health. Dairy foods contribute 70.3 % of calcium, 16 % of magnesium almost all of the vitamin D, 18.2 % of vitamin B12, 15 % of zinc, and 25 % of riboflavin in the typical US diet [4]. Given that dairy intake is an essential resource of bone-building nutrients in the western diet and plays an important role in maintaining bone health, it is essential to address the issue of nutritional equivalency of dairy foods in order to optimize bone health.

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