Review

Dairy and Bone Health

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Bone health is the resultant of bone mass, bone architecture, and body mechanics. Nutrition supports all three components, with the principal nutrients concerned being calcium, protein, and vitamin D. Potassium, magnesium, zinc, and several vitamins are also involved to varying extents. Given modern food sources, it is difficult to devise a diet that is "bone healthy" without including three servings of dairy per day, not just because of dairy calcium, but dairy protein and potassium as well.

Key teaching points

- Low fracture risk (bone health) depends upon bone mass, bone architecture, and body mechanics (falls avoidance).
- Nutrients influence all three components.
- Calcium, protein, and vitamin D are critically important for bone health, particularly as they are often deficient in American diets.
- Dairy foods are the best readily available sources for these nutrients, and diets low in dairy will almost always be low in one or more of the nutrients needed for healthy bones.

INTRODUCTION

Osteoporosis is a serious health problem in the United States, causing significant morbidity and mortality. In humans, bone mass increases steadily until ages 20–30, depending on the site measured. A higher peak bone mass provides a cushion to offset late life loss of bone and thereby lessens the risk for osteoporosis [1]. It is believed that genetic factors determine up to 80% of peak bone mass with the remainder influenced by environmental factors such as exercise, smoking, medication and nutrition [1]. However, these categories are not clearly separable, as genetics influences response to environmental factors. A good example is the fact that skin pigmentation (genetics) affects vitamin D status through response to solar radiation (environment), thereby altering efficiency of utilization of a nutrient (calcium). This brief review presents a few key points of bone biology as it is involved specifically in the disease, osteoporosis, and summarizes the evidence for the role of nutrition — and especially dairy foods — in maintaining bone health.

BONE STRUCTURE AND FUNCTION

The bony skeleton is an organ that serves both a structural role that supports, protects and provides mobility, as well as a reservoir for essential minerals — primarily calcium and phosphorus — that are important for numerous body systems. Bone is a composite of inorganic salts, largely hydroxyapatite crystals [$Ca_{10}(PO_4)_6(OH)_2$] along with small amounts of sodium, magnesium, potassium, zinc and carbonate, bound to an organic matrix of protein. Type I collagen is the major protein of bone, making up about 95% of the organic matrix that functions to provide strength (mainly to resist tension) while the remaining 5% is made up of noncollagenous proteins and proteoglycans. Within and between collagen fibrils, hydroxyapatite crystals function to provide strength and rigidity (mainly to provide resilience to physical impact).

Structurally, the skeleton consists of two types of bone — cortical (compact bone) and trabecular (cancellous) bone. Cortical bone is dense, compact and has a slow turnover rate of ~3% per year. It is found on the outer layer of all bones and in the shafts of the long bones, and comprises about 80% of the

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total mass of the skeleton. Trabecular bone is much less dense and is metabolically more active, with a turnover rate of ~26% per year. It makes up about 20% of the skeletal mass and is found mainly in the axial skeleton and at the ends of the long bones. True volumetric bone mineral density (vBMD) is the amount of mineral in a defined volume of bone and is usually expressed as grams of mineral per centimeter cubed (cm^3) of bone structure. Areal mineral density (aBMD, or simply BMD), the variable usually measured by dual X-ray absorptiometry (DXA), is the mass of bone mineral lying behind a defined bone area.

REMODELING

Bone is continually being broken down and rebuilt throughout life for the purpose of maintaining bony integrity and for reshaping bone to accommodate changing mechanical loads. This process, termed bone remodeling, occurs when small, discrete volumes of old bone are removed (resorption) and subsequently replaced with fresh new bone (formation). Numerous sites throughout the skeleton undergo remodeling activity at any given time resulting in a significant fraction of the adult skeleton being replaced every year. If resorption and formation are coupled correctly, remodeling results in little change in the mass of the bone. Remodeling rarely results in an increase of overall bone. The basic purpose of remodeling is to replace old or damaged bone. However, as remodeling both releases calcium from bone and takes up calcium when new matrix mineralizes, this bi-directional flux of calcium also serves to support the body's regulation of body fluid calcium concentration. Whenever calcium intake is inadequate, remodeling rate will be in excess of the level needed to repair structural damage [2].

PEAK BONE MASS DEVELOPMENT

From birth through adolescence, the skeleton increases in length and breadth. When long bone growth is complete, the ends of the bone fuse with the shaft in a process known as epiphyseal closure, whereupon growth in length ceases, but skeletal mass continues to increase for up to 10–15 years through the process of bone consolidation. This point is called the time of peak bone mass, occurring sometime about age 30, after which skeletal mass as a whole is stable until about age 50, when it starts to decline. During the first two decades of life 90% of peak bone mass is acquired.

OSTEOPOROSIS

Osteoporosis is a condition characterized by low bone mass and bone microarchitechtural deterioration, leading to skeletal fragility and an increased risk of fracture. The costs of osteoporosis treatment and fracture care reached approximately $19 billion in 2005 in the U.S., and is expected to rise to $25.3 billion by 2025 [3]. The estimated direct expenditures for osteoporotic hip fractures was $18 billion dollars in 2002, and is rising. Osteoporosis and low bone mass are major public health threats for 44 million men and women in the U.S. Nearly 34 million are estimated to be at increased risk for osteoporosis because of low bone mass. Of the estimated 10 million Americans who have osteoporosis, 80% are women and 20% are men. Men, especially elderly men, can and do get osteoporosis. After age 50, 1 in 2 women and 1 in 4 men will have an osteoporosis related fracture [3].

Much of the burden of osteoporosis can be prevented by focusing on certain lifestyle changes. Osteoporotic fractures involve a number of factors beyond bone weakness, including falls, slow reflexes, sarcopenia, and inadequate soft tissue padding. Nutrition plays a critical role in reducing the risk of osteoporosis through its effect on all of these fragility factors, especially on the development and maintenance of bone mass. Maintaining optimal nutrition and weight bearing activities have been shown to reduce the risk of osteoporosis by as much as 50% [4,5].

Prevention of osteoporosis is best ensured by understanding the factors responsible for the disease. Risk for fracture depends upon bone strength, which depends on the bone architecture, bone mass, and the inherent strength of the bony material. Areal BMD is inversely correlated to fracture risk and is one component that is modifiable by such environmental factors as nutrition (calcium, vitamin D, vitamin K, sodium, protein, and magnesium intakes), physical activity, alcohol and smoking. Attainment of maximal peak mass (BMC) and reduction of unnecessary bone remodeling (see below), are the best strategies for prevention of osteoporosis. Childhood is the best time to form the lifestyle behaviors that promote optimal bone health. In this respect, osteoporosis is recognized today to be a "pediatric disease with geriatric consequences" [6].

CALCIUM INTAKE AND BONE HEALTH

The primary role of calcium in the body is structural, providing the rigidity necessary for the skeleton and teeth to function mechanically. Bone contains about 99% of the body's calcium. Calcium in body fluids also exerts critical metabolic functions, binding to proteins, and operating as a signal transmitter and protein activator within cells. Muscle contraction and nerve transmission are two of the many body functions that rely on calcium for activation. Additionally, calcium is involved in blood clotting. Calcium is so important to the body that extracellular fluid calcium concentrations are tightly controlled within a narrow range. Regulation of blood calcium levels involves a process utilizing parathyroid hormone (PTH), vitamin D, and calcitonin. PTH is released from the parathyroid gland when blood calcium levels drop. PTH acts to increase phosphate excretion and calcium reabsorption in the kidney. It also acts at the skeletal level to stimulate bone resorption by osteoclasts. Finally, PTH causes vitamin D activation to $1,25(OH)_2D_3$ in the kidney, resulting in increased calcium absorption in the gut. Calcitonin is a hormone released from the clear cells of the thyroid in response to high serum calcium. Calcitonin acts directly on osteoclasts to inhibit bone resorption in order to reduce the amount of calcium moving from bone into the bloodstream.

The relationship between calcium intake and bone density has been well studied in children and adults. A critical analysis by Wosje and Specker concluded that bone mineral density is increased in children and adolescents as calcium intakes increase [7]. Epidemiological studies report that a lifetime of high calcium intakes can reduce fracture risk by as much as 60% [8]. A recent study of Caucasian postmenopausal women from the National Osteoporosis Risk Assessment study (NORA) reported that lifetime calcium intake was associated with reduced risk for osteoporosis, with the odds ratio (OR) = 0.80 (95% confidence interval (CI): 0.72–0.88). Current calcium or vitamin D intakes were also associated with reduced risk for osteoporosis over three years, OR = 0.75 (95% CI: 0.68–0.82) and OR = 0.73 (95% CI: 0.66–0.81), respectively [9]. From the early years and further on, calcium intake is positively associated with bone mass [2, 10–12]. Nieves et al estimated that an increase in teenage calcium intake from 800 to 1,200 mg per day would increase hip bone density by 6% [10]. Heaney assembled the results of research conducted since 1975 on bone health and calcium intake [13], reporting that of 52 investigator-controlled calcium intervention studies, 50 showed that increasing calcium intakes resulted in reduced bone remodeling, better calcium retention, reduced age-related bone loss, or reduced fracture risk.

Heaney also reported that of 86 observational studies, 64 reported relationships in favor of increased calcium intakes, with reduced fracture risk, bone loss or improved bone mass. Additionally, of those studies specifically evaluating dairy sources of calcium, approximately 75% supported the conclusion that increased calcium from dairy foods is protective of the skeleton. After submission, but before publication, 13 additional studies were published, all 13 reported positive effects of calcium on bone health [13]. Since then, more than 100 additional studies have been published, with the proportions of positive and null studies remaining at about 75–80% and 20–25%, respectively.

A little appreciated, but probably very important, aspect of the relationship of calcium intake and bone health is the effect of calcium on bone remodeling [14]. Although osteoporosis is classically defined in terms of low bone mass, evidence suggests that the fragility of osteoporosis is due as much or more to the accelerated remodeling of bone that follows menopause in women, accompanies low calcium intake, and is found in most cases of osteoporosis [14,15]. High calcium intakes, by suppressing PTH secretion, reduce that elevated remodeling, and in the process reduce the bony fragility that is the true hallmark of osteoporosis. This conclusion is supported by the fact that fracture risk reduction in the calcium treatment trials starts immediately upon beginning supplementation, long before there would have been any effect on bone mass [4,5].

It is important to note that calcium, like most nutrients, exhibits threshold characteristics, that is, the effects briefly summarized here accrue only in individuals with low intakes. Once intake is adequate, consuming additional calcium confers no further benefit. The intakes at which this transition occurs varies from individual to individual and is the basis for determining both the average requirement and the RDA. Finally, it is critical to understand that locating this transition point can only be determined by multi-intake feeding studies, such as that of Jackman et al. [16], or by analyses such as that of Matkovic and Heaney [17]. Balance studies using zero balance as an indicator of adequacy [18] determine only the intake needed to maintain the skeletal status quo. Such intakes may well be inadequate to support the skeletal program contained in the genetic code (just as the energy intake needed to sustain body weight in a famine victim is manifestly inadequate to support ideal body weight and functioning).

VITAMIN D AND BONE HEALTH

Vitamin D can be obtained from sunlight and from the diet. Fatty fish, fortified milk, and other fortified foods are the main dietary sources of vitamin D. The best recognized function of vitamin D is to support calcium absorption and thereby maintain blood calcium and phosphorus levels. Vitamin D enhances calcium absorption by stimulating active transport in the gut, and is absolutely necessary for adequate intestinal calcium absorption. Additionally, vitamin D works with PTH to enhance renal calcium reabsorption. When serum calcium levels drop, PTH is released and acts on the kidney to increase 1-α-hydroxylation of 25-hydroxyvitamin D, converting it to its active form. Vitamin D also has a direct effect on bone. Osteoclast formation, differentiation, and bone resorption are stimulated by vitamin D. Severe deficiency of vitamin D results in osteomalacia in adults and rickets in children, a clear indication of the important role of vitamin D in maintaining skeletal integrity. Insulin-like growth factors (IGF) I and II act with vitamin D to increase production of osteocalcin. Vitamin D has been shown to stimulate IGF-II production and to upregulate insulin-like growth factor binding protein $(IGFBP)_5$ mRNA.

Data from the 1999-2000 NHANES study suggest that essentially no adults over age 51 are meeting vitamin D needs with foods [19], which is undoubtedly one factor responsible for the reported increase in vitamin D deficiency [20,21]. Studies on the effects of vitamin D supplementation or status on bone health have yielded mixed results in children [22] and adolescents [23]. In older adults, however, the evidence for a benefit on bone health is clearer. Increasing vitamin D intakes in older adults has been shown to reduce risk of fracture and bone loss [24–28]. A meta-analysis by Bischoff-Ferrari et al. reported that 700 to 800 IU/day of oral vitamin D reduced nonvertebral fractures by 23% and hip fractures by 26% compared to placebo, averaged over an aggregate of 12 randomized, controlled trials [29].

PROTEIN AND BONE HEALTH

About half of the volume of bone material is protein. Bone remodeling involves the synthesis of new protein matrix and requires an ongoing supply of fresh dietary protein if bone removed during resorption is to be replaced. Dietary protein has been shown in some studies to increase urinary calcium excretion; however this may be problematic only in those with low calcium intakes [30]. Most studies indicate that dietary calcium and protein interact constructively on bone so long as the intake of each is at least adequate [31–33]. Studies have reported a positive relationship between protein intake and BMD [34], reduced incidence of fracture [35–38], and reduced rate of bone loss [35,39]. Dietary protein stimulates insulin-like growth factor I (IGF-I) production, which is important in bone growth [31,32]. Elderly patients with hip fractures were shown to have low serum protein levels, with improvements in outcomes seen with protein supplementation [40,41]. A study by Dawson-Hughes and Harris in 342 healthy men and women aged 65 and older found that, in participants supplemented with calcium and vitamin D over three years, those with higher protein intakes had improved total body and femoral neck BMD compared to unsupplemented subjects [30]. The interaction of protein and calcium has been discussed in greater detail elsewhere [42], and the role of protein itself has been recently reviewed by Conigrave et al. [33].

OTHER MICRONUTRIENTS AND BONE HEALTH

There are many other micronutrients that are intricately involved in, and important for the health of bone, including vitamin K [43–47], sodium [48–51], phosphorus [52], magnesium [53], potassium [54–56], vitamin B_{12} [57] and zinc [58]. More recently, fruit and vegetable intake has been associated with bone health. A diet rich in bicarbonate and in potassium rich foods reduced bone turnover in 23 to 76 year old men and women over a one month period. This diet included fruits and vegetables as a source of bicarbonate, and dairy products for potassium [55].

Vitamin K

Vitamin K is involved in bone health because of its function in the carboxylation of osteocalcin, a protein involved in bone formation. Some studies suggest that vitamin K insufficiency is associated with low BMD and increased fractures [43]. A recent longitudinal study of healthy children found that over two years, better vitamin K status was associated with a greater increase in bone mass in 11-year olds [59]. In post-menopausal women supplemented with 45 mg/day vitamin K_2 for 3 years, indices of bone strength of the hip were maintained as compared to a significant decrease in women given placebo [60]. A systematic review conducted by Cockayne and colleagues reported that out of 13 randomized controlled trials, 12 found that supplementing with vitamin K reduced bone loss [45]. An even more recent review [44], however, found the data to be less convincing. Recently, the focus in the literature has shifted mainly to the best way to supplement vitamin K (K_1 or K_2) and research related to surrogate measures for bone strength.

Sodium

A high salt diet has long been suspected of being detrimental to bone health because of increased urinary calcium excretion in the short term, although long term outcomes are less certain [61]. The DASH diet which emphasizes fruits, vegetables and low fat dairy products was found significantly to reduce bone turnover markers after 30 days at all three levels of sodium intake (1500 mg/d, 2300 mg/d and 3450 mg/d), with the greatest benefit seen in the reduced sodium group as urinary calcium excretion decreased [50]. More research is needed to determine the effects of the typical American diet, high in sodium, on bone health over time.

Phosphorus, Magnesium, Zinc

Phosphorus. Eighty to 90% of the mineral content of bone is made up of calcium and phosphorus, and 85% of the phosphorus found in the body is in the skeleton [1] Consuming enough phosphorus, therefore, is necessary for bone growth and mineralization. Alternatively, a high phosphorus intake, if accompanied by a low calcium intake, may be deleterious to bone due to increased parathyroid activity, possibly resulting in bone loss [62,63]. However, it is likely in this connection that the increase in PTH is due mainly to the low calcium intake, as the same effect is found at normal phosphorus intakes [64] if calcium intake is low. The controversy surrounding cola beverages is most likely not an issue because of their phosphorus content. Rather their association with fracture and BMD is most likely due to their displacement of milk from the diet [1].

Magnesium. Magnesium is found in the skeleton, and magnesium deficiency has been considered to be a risk factor for osteoporosis [1]. In a study of 70–79 year old men and women, magnesium intake from food and supplements was positively related to whole body BMD in white, but not black individuals

[65]. Magnesium has also been thought to be necessary for calcium absorption, but the evidence for this connection is scant. Moreover, it is worth noting that all the successful calcium trials [e.g., 4,5,22] showed fracture reduction or protection of bone mass without employing supplemental magnesium, indicating that magnesium status of the treated group was sufficient to permit a skeletal response to calcium. In any event, much more research on the relationship between magnesium and bone health is needed.

Zinc. Thirty percent of the zinc that is stored in the body is found in bone. Zinc is an important and abundant trace element. In addition to its presence in the mineralized component of bone, zinc is found in enzymes required for bone metabolism including alkaline phosphatase and carbonic anhydrase. Zinc deficiency is associated with reduced bone mass and stunted growth, however supplementation trials in adult humans are lacking.

Potassium

Potassium affects calcium homeostasis via urinary calcium losses. A low potassium diet causes elevated urine calcium, while the reverse is also true. It is possible that a high potassium intake can offset the bone resorption seen with a high salt diet [66]. A study of 60 postmenopausal women compared a high salt diet plus placebo to a high salt diet plus potassium citrate for 4 weeks. Those women consuming the potassium citrate excreted significantly less urinary calcium and had lower bone resorption activity than the placebo group [67].

Vitamin B_{12}

Vitamin B_{12} may be involved in bone health via an effect on osteoblast proliferation [68], and/or through its involvement with homocysteine metabolism. Homocysteine has been shown to hinder bone mineralization and collagen crosslinking and has been linked to osteoporotic fractures in the elderly. Gjesdal and colleagues reported a significant inverse association between plasma homocysteine and BMD in 5408 men and women aged 47–75 years [68]. A study of 194 elderly adults found a significant correlation between vitamin B_{12} status and BMC and BMD in women, but not men [69]. Utilizing NHANES data, Morris et al. found a positive relationship between serum vitamin B_{12} and BMD, and an inverse relationship between serum homocysteine and BMD in men and women over age 55 [70].

DAIRY PRODUCTS AND BONE HEALTH

Dairy products provide more protein, calcium, magnesium, potassium, zinc and phosphorus per calorie than any other typical food found in the adult diet [13]. Studies measuring the impact of dairy products on bone have been described by Heaney [13] and by the 2005 Dietary Guidelines Advisory Committee (DGAC) [71]. The Dietary Guidelines report found that seven out of seven randomized controlled trials, and 25 out of 32 observational studies showed a significantly positive association between dairy food intake and bone mineral content (BMC) or density (BMD). Since that review, four additional randomized controlled trials have been conducted, and all have shown positive relationships between dairy intake and BMC or BMD [72–75]. A 12 month intervention trial (the Postmenopausal Health Study) reported that those women who received approximately 1200 mg calcium and 7.5 mcg vitamin D (300 IU) through dairy products had significantly greater improvements in hip, spine and total body BMD than those participants who received a calcium supplement only or a placebo control group [76]. A recent meta-analysis of dairy products and dietary calcium on BMC in children reported that total body and lumbar spine BMC were significantly increased in children with higher intakes [77].

BMD (or BMC) is a surrogate measure for bone strength, while incidence of fracture is the key functional outcome measure. According to the 2005 DGAC report, five of eight observational studies found dairy consumption to be significantly associated with reduced fracture risk [71]. The other studies were null; there were no negative studies. To our knowledge, no randomized controlled trials have been conducted on the relationship between dairy food intake and fracture risk. There have, however, been randomized controlled trials reporting reduced fracture incidence with elemental calcium [78,79] or calcium with vitamin D [4,5,80]. Nieves et al. analyzed dietary questionnaires collected from 76,507 postmenopausal Caucasian women with 2,205 newly reported osteoporosis related fractures. Although risk of fracture was not associated with calcium or vitamin D intake, adequate calcium, with or without vitamin D reduced the odds of osteoporosis [9]. A 3-year cohort study conducted in Spain of 5,201 women, aged 65 or older, found that calcium intake from dairy products of less than 250 mg/day was independently associated with risk of fracture in this population [81]. The 2005 DGAC also found, through the use of food pattern modeling, that recommendations for potassium as well as for calcium, at most calorie levels, could not be reached until patterns were adjusted to include three cups of milk per day [71,82][68,79]. Additionally, Gao et al [83], using NHANES 2001–2002 data, showed that diets could not be constructed that simultaneously met adolescent calcium needs and were dairy-free. It is important to stress as well that soy-based beverages and dairy milk are not nutritionally equivalent [84,85], in part because the amino acid composition of their proteins differs, and in part because soy beverage calcium is frequently much less available than dairy calcium.

EFFECTS OF MILK AND MILK PRODUCTS VS. CALCIUM SUPPLEMENTS ON BONE

Most of the studies exploring the relationship between calcium intake and bone status (bone mass, calcium balance, bone loss, or fractures) have involved calcium supplement sources, rather than food sources, largely because of lower study cost and greater ease of ensuring compliance. It is generally held that, for the same bioavailability, one source of calcium is much the same as another. This is because the calcium ions, once absorbed, lose their source identity. Thus, benefits shown for one calcium source can be presumed to be applicable to others as well, given equivalent absorbability. It is reasonably well established that the anion of calcium supplements makes relatively little difference. The carbonate and citrate salts (for example) are absorbed and retained with equal efficiency [86,87]. In brief, skeletal effects for one calcium source can be extended to other calcium sources unless there is clear proof to the contrary. The only important exceptions are calcium sources that contain additional nutrients that affect bone health in their own right. We have already commented on the synergistic effect on bone of protein, vitamin D, potassium, and calcium.

In reviews of studies on the quantitative impact of calcium on bone it was concluded that milk product consumption is at least as good as that observed with calcium supplements [13,71]. In follow-up of studies using foods fortified with milk-extracted calcium phosphate it was shown that bone mass accrual was maintained well after the intervention period [88], whereas in studies using calcium supplements the gain in BMD observed during the supplementation period disappeared when evaluated during post-supplement follow-up [89,90]. These studies suggested that milk and milk products provide a longer lasting skeletal benefit than that seen with calcium supplements. Cheng et al. examined the effects of food-based calcium (cheese) versus supplements of calcium and vitamin D on bone mass in adolescent girls [74]. In this two year randomized controlled trial, four groups of girls aged 10 to 12 years old with baseline calcium intakes of 664–680 mg/d were supplemented with: a) 1000 mg of calcium from supplemented dairy products (mainly low-fat cheese); b) 1000 mg calcium phosphate + 200 IUs vitamin D; c) 1000 mg calcium phosphate; or d) placebo control. Results showed the following benefits of using cheese to augment calcium intake: a) greater positive change in cortical thickness of the tibia compared to placebo, calcium, or calcium + vitamin D groups ($P = 0.01$, 0.038, and 0.004, respectively); and b) higher whole-body BMD compared to placebo ($P = 0.044$) when compliance was $>50\%$. No differences were observed for other bone sites (i.e., radius, femoral neck, total femur, and lumbar spine). This is the first randomized controlled trial comparing the effectiveness of food calcium vs. supplements. The authors suggested that the better result seen with cheese may be due to: a) better absorption of calcium from dairy due to lactose or caseinphosphopeptides; b) ideal distribution of calcium intake during the whole day versus larger amounts of supplements twice a day; and c) higher intakes of protein, magnesium, or other micronutrients from dairy products [74]. Additionally, as discussed earlier, the cheese ensured a high protein intake, thus supplying both of the nutrients essential for bone building.

Other nutrients associated with calcium sources, such as vitamin D (often incorporated into supplements), phosphorus, magnesium, and potassium found principally in dairy foods, are likely to make a dairy source more effective than one containing calcium alone. Vitamin D inadequacy, for example, is even more common in the population than is calcium inadequacy [91]. Because both nutrients are important for bone, supplementing both of them produces a greater benefit than supplementing just one.

The available evidence supports the conclusion that optimal skeletal health requires adequate intakes of *multiple* nutrients, not just calcium. It is reasonable to conclude that calcium sources which provide these other nutrients will be at least as efficacious as the calcium supplements used in anti-fracture efficacy trials, and very likely, more so.

ESTIMATED HEALTHCARE SAVINGS ASSOCIATED WITH ADEQUATE DAIRY FOOD INTAKE

The economic impact of improving dairy product consumption for Americans has been estimated by McCarron and Heaney [92]. Dairy food intake was shown to be important in reducing disease burden of several medical conditions including obesity, hypertension, type 2 diabetes, osteoporosis, kidney stones, certain pregnancy outcomes, and some cancers. The authors searched the medical literature for both randomized controlled trials and observational and prospective longitudinal studies on the relationship between dairy calcium or dairy product consumption and the prevalence of these disorders. Direct costs for all osteoporotic fractures in the U.S. combined, were estimated to be $17 billion for 2002. The authors calculated that by increasing intake of dairy foods to the recommended 3–4 servings per day, a reduction of at least 20% in osteoporosis-related health care costs could be achieved. This translates to $3.5 billion savings each year, reaching cumulative savings of $14 billion over four years [92].

CONCLUSION

The studies reviewed above highlight the importance of multiple nutrients for bone health. The Surgeon General's report on *Bone Health and Osteoporosis* recognizes that calcium, vitamin D, other essential nutrients including phosphorus, protein, potassium, magnesium, zinc, vitamin A and vitamin C, are vital to bone health [93]. Milk and milk products are described in the 2005 DGAC as primary dietary sources for most of these nutrients [71]. Three servings of low-fat milk provide 25–87% of the recommended intakes for calcium, vitamin D, vitamin A, phosphorus, protein, potassium and magnesium for adult females [94].

Osteoporosis is a disease with many contributing factors. Although heredity has great influence over the potential for developing osteoporosis, there are many modifiable environmental factors that can significantly alter risk, including exercise and nutrition. Health care professionals should emphasize the importance of adequate servings of fruits, vegetables and low-fat dairy for the best possible defense against the disease.

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