IS MILK REALLY GOOD FOR ALL?

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Insights

During rotation in trauma surgery, a patient asked if it was possible that he was more prone to bone fractures because he drank little milk as a child. No one could give him the answer. This kept us wondering: is there a connection between intake of dairy and bone health or bone fractures? We decided to do an analysis on this topic.

Background

During childhood, fractures are common: approximately 30-50% of all children experience fractures [1]. The incidence of fractures is the highest in boys, particular during puberty [2,3]. Several studies demonstrated that impaired bone health is related to the risk of fractures in children [2,4]. Fracture risk at any age is, amongst others, determined by bone mineral mass (the number of minerals in a certain volume of bone), the geometry and microstructure of bone. These factors determine the strength, elasticity and fragility of the bone, which varies between a peak bone mass at the end of puberty to an impaired bone mass in elderly [5]. Major determinants of peak bone mass and strength are genetics and the loading of the bone (by physical activity). However, several factors during childhood and adolescence may affect the process of achieving peak bone mass (Figure 1). Nutrition is one of these factors, with in particular calcium and protein intake [6]. The largest quantity of calcium is obtained from milk and dairy foods. Traditionally, milk and dairy products are said to be good for your bones. The aim of this article is to shed some light on the relationships between milk and dairy products intake and bone health.

Bone growth

Bone consists of minerals (60%), anorganic matrix (30%) and water (10%), which makes it a composite material [7]. The development of the skeleton continues until the end of the second decade of life, when peak bone mass is achieved. Genetic factors make up for 60-80% of the variance in peak bone mass and strength [5]. The remaining influencing factors include nutrition, endocrine status (such as sex hormones, vitamin D, growth hormone and Insuline-like Growth Factor 1 (IGF-1)), intercurrent illness and exposure to a variety of risk factors such as cigarette smoking and excessive alcohol intake [5,6]. Physical activity is another important influence on bone. Research showed that physical activity patterns in adolescence accounted for 10-22% of adult bone variance in a study about health in young women [8]. The structural bone composition and thereby the bone mass is dependent on the dietary supply of calcium, phosphate and protein [2,5,6]. The three aforementioned nutrients require a normal vitamin D status for being integrated into the bone material and their combination reduces bone resorption (i.e. breaking down) and stimulates bone formation [7]. The greatest amount of dietary calcium and other nutrients important for bone health are obtained from milk and dairy foods [6]. Resorption and formation of bone occur during adulthood under control of three types of bone cells [7]. Osteoblasts are the bone forming cells. The osteoblasts form the organic matrix, made of collagen proteins, and deposit the collagen fibres on calcium and phosphate (the two main components of bone mineral crystal). Osteoclasts are the cells that break down the bone by resorbing the mineral and matrix of the bone tissue. The

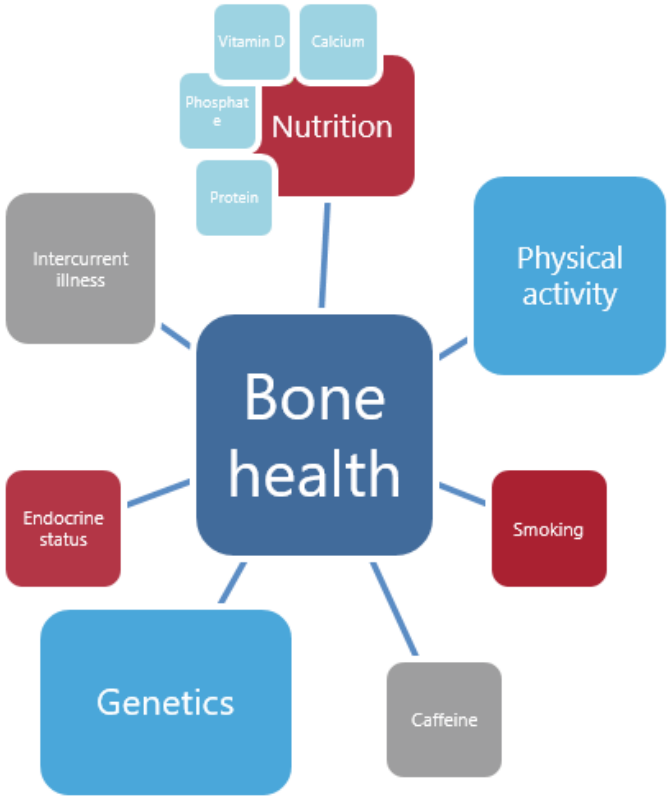

Figure 1: Important factors for bone health.

activity of these cells determines the bone mass and the amount of calcium in the blood. Osteocytes form an interconnected network in bone and regulate the activity of the osteoblast and osteoclast [7]. During physical activity, the osteoblasts are active in bone formation, while during calcium deficiency osteoclasts are active in breaking down the bone to maintain calcium levels in the blood.

Calcium, vitamin D and bone

For a long time, the positive effect of dairy consumption on bone health was attributed to calcium alone [9]. According to Voedingscentrum and U.S. National Institute of Health the recommended amount of calcium is between 200 and 1,200 mg/day [10,11]. This corresponds to one to six glasses of milk per day. However, new evidence shows that dietary phosphate and protein can enhance calcium levels by stimulating intestinal absorption and renal tubular reabsorption of calcium [7,12]. Calcium enters the body through the intestine via two

different mechanisms: an active, vitamin D-dependent transport across the proximal duodenum, and a facilitated diffusion in the small intestine [6]. Several factors influence calcium balance, for instance calcium absorption is modulated by the food source and vitamin D status, which in turn is depending on both dietary intake and production in the skin by exposure to ultraviolet light [13]. Urinary calcium losses are influenced by total dietary (animal) protein, caffeine intake and smoking [14]. An adequate calcium and vitamin D intake increases bone mineral density during skeletal growth and it prevents bone loss and osteoporotic fractures in the elderly [15]. In children aged 3-18, a positive effect of calcium supplementation was shown on total body bone mineral content with daily doses of calcium ranging between 300 and 1,200 mg/day [16]. It is suggested that calcium supplementation may transiently increase bone mineral density by reducing the rate of bone remodelling [11]. In the situation of inadequately low vitamin D and calcium supply, there will be a decrease in the intestinal calcium absorption. This, in turn, causes an overproduction of parathyroid hormone (PTH) [7]. In bone, increased parathyroid hormone stimulates bone resorption, causing calcium levels to rise again. All factors that affect calcium balance, including dietary calcium intake, calcium supplementation and vitamin D, may thus positively affect bone development.

Proteins and bones

Dietary protein provides the body with the necessary amino acids for building the bone matrix and, at the same time, it stimulates IGF-1, which is important for bone formation [17]. IGF-1 is produced by osteoblastic cells [7]. An increase in the circulating level of IGF-1 enhances the renal production of the active form of 1,25-dihydroxy vitamin D, which then stimulates the intestinal absorption of both calcium and phosphate. The tubular reabsorption of phosphate is also increased by IGF-1. This leads to the activity of IGF-1, increases the concentration of calcium and phosphate and influences the bone mineralization process positively [7].

Protein intake in children and adolescents influences bone growth and bone mass accumulation. For example, in a prospective longitudinal study in healthy boys and girls (aged 6-18), dietary intakes were recorded for four years [18]. At the radius shaft, bone mass and size were measured by computerized tomography. The study found a significant positive association between long-term protein intake and bone circumferences, cortical area, bone mineral content and a calculated strength index that indicates bone stability [19]. Overall, protein intake accounted for 4% of the variance in bone variables.

Phosphate and bones

Bone contains about 99% of the total calcium and 80% of the phosphate in the body. Their ratio in bone is 2.2, which is similar to that measured in human milk [7]. Calcium and phosphate both have a structural role in the bone matrix, as well as a positive influence on the activity of bone forming and an inhibitory effect on resorbing cells [20]. Phosphate is involved in the maturation of osteocytes. In the kidney, increased phosphate intake reduces urinary calcium loss and increases calcium balance [7].

Milk and bones

One liter of milk provides calcium, phosphate, vitamins and approximately 35 grams of protein, among which is 'whey protein' that contains growth-promoting elements [21]. Long-term milk avoidance is associated with smaller stature and lower bone mineral mass in growing children. During childhood and adolescence, low milk intake may increase the risk of prepubertal fracture. In children with cow milk allergy, who thus avoided drinking cow milk for a long period, fracture risk was 2.7-fold higher than in a matched birth cohort [22]. A prospective cohort study of self-reported fracture risk at follow-up showed that fracture risk was similar for meat or fish eaters and vegetarians, but was higher in vegans. The percentage of subjects consuming less than 700 mg calcium per day was 15.0% for meat and fish eaters, 18.6% for vegetarians and 76.1% for vegans. This higher fracture risk among vegans would be the consequence of their lower calcium intake [23]. The advantages of dairy consumption are strongest during growth, as shown by a study by Kalkwarf et al. that investigated the effects of milk intake during childhood and adolescence on adult bone density and osteoporotic fractures. The study was conducted in The US on 3,251 non-Hispanic postmenopausal women. In women with low milk intake during childhood (5-12 years of age) and adolescence (13-17 years), a lower bone mass was found in adulthood. Low milk intake during childhood was associated with 11% of osteoporotic fractures in women later in life [24].

Bioactive components of milk may directly affect the bone. For example, milk whey protein suppressed bone resorption and prevented bone loss caused by ovariectomy in aged rats [25]. Both age and ovariectomy decrease oestrogen production, which is an important hormone for bone health. Furthermore, a possible effect of milk is inhibition of bone turnover. A period of 6 weeks in which milk was supplemented to thirty healthy postmenopausal women induced a decrease in several biochemical variables compatible with diminished bone turnover [25].

Are dairy products really that good?

Besides the studies that described positive effects of dairy and calcium intake on bone health, there have been a few articles that concluded otherwise. One of these studies describes that calcium intake could only be responsible for 1% of the interindividual variability in bone mass and that the habitual intake of calcium throughout life is important for bone density, instead of the present dairy intake [14]. In the studies that researched the relationship between fracture risk in children and dairy product intake, one of them found no association between dairy product intake and the occurrence of bone fractures in school-aged children [26]. Another research found that high total calcium intake was associated with reduced fracture incidence, but there was no association with milk consumption alone and fracture risk in 8-16 year olds [27]. This reflects that total calcium intake is more important than intake of milk alone. In a study that assessed total dietary calcium, low bone density was more common in both boys and girls with fractures compared to those without fractures. Girls aged 11-15 years with fractures reported lower average calcium intakes from dairy products currently and between 6-10 years than age-matched controls [28]. In boys, the calcium intake in the groups with and without fractures was similar [29]. Regarding research on the effect of calcium supplementation (300-1,000 mg/day) on bone mineral content and bone mineral density in children and adolescents, there was a 1% - 6% significant increase in bone mineral density or bone mineral content, but the effect did not persist after suppletion was terminated [14]. Results from calcium suppletion trials like these are mostly not mirrored in research that uses total dietary calcium intake or dairy products [14]. Dairy products contain protein, sodium and in some cases supplied vitamin D. These nutrients influence calcium balance and thus bone mineralization, as described earlier. Besides the positive effects on bone, in particular sodium and animal protein tend to increase calcium excretion [14]. Most controlled studies of dairy supplementation show that very low calcium intakes (<400 mg/day) may be harmful to bone development, but increases in dairy or total dietary calcium intake (>400-500 mg/day) are not correlated with or a predictor of bone mineral density or fracture rate in children or adolescents [14,30,31].

Conclusion

Although some studies question the positive effects of dairy on bone health, it is not easy to draw an unambiguous conclusion. The majority of available research states that milk and dairy products are reliable sources of calcium as well as other nutrients important for bone health. The advantages of dairy consumption on bone health are suggested to be the strongest during growth, but bone mineral density and fracture risk are not solely dependent on calcium intake. It appears that there is a minimum of calcium needed for the positive effect on bone mineral density in children with skeletal growth as well as in elderly in preventing osteoporotic fractures. Most western children seem to meet the required amounts and do not need higher milk intake or supplements. In elderly, factors like hormone regulation and activity also play an important role on bone mineral density. It has not been demonstrated that the effect of dairy or calcium consumption persists after consumption is terminated. Still, the answer to the question about the relationship between drinking little milk in childhood and bone fractures and bone health is not that easy. Besides dairy intake, more factors are relevant for bone health. For instance, physical activity, smoking, drinking caffeine and age are important to consider when talking about bone health. Given the many bone influencing factors that also influence each other, it is difficult to design a good study design in which a large group of people varies in only one of these factors. This is important to highlight when explaining this to patients.

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