Joint Bone Spine 84 (2017) 275–281

Available online at ScienceDirect www.sciencedirect.com

Elsevier Masson France EM|consulte www.em-consulte.com/en

Review

Osteoporosis: Is milk a kindness or a curse?

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ARTICLE INFO

Article history:
Accepted 18 May 2016
Available online 8 October 2016

Keywords:
Cow's milk
Fracture
Bone mineral density
Bone turnover markers

ABSTRACT

Cow's milk is often severely criticized as a cause of multiple health problems, including an increased risk of fractures. A close look at the scientific literature shows a striking contradiction. On the one hand, experimental studies of surrogate markers (e.g., bone turnover markers and bone mineral density [BMD]) usually indicate benefits from drinking cow's milk. On the other, the findings from epidemiological studies are conflicting and disconcerting. In all age groups, including children and postmenopausal women, consuming cow's milk, powdered milk supplements, or whey protein is associated with a slower bone turnover and unchanged or higher BMD values. These benefits are particularly marked in populations where calcium deficiency is prevalent, for instance in Asian countries. No interventional studies have addressed the fracture risk potentially associated with drinking cow's milk. The only available data come from epidemiological observational studies, whose results are conflicting, with a lower fracture risk in some cases and no difference or a higher risk in others. Several hypotheses have been offered to explain these findings, such as a deleterious effect of D-galactose, lactose intolerance, and acid overload. Epidemiological studies face many obstacles when seeking to detect effects of a single food, particularly the multiplicity of interactions among foods. Furthermore, reliable dietary intake data must be collected over prolonged periods, often long before the occurrence of a fracture, and defective recall may therefore introduce a major yet often unrecognized bias, particularly in populations where calcium deficiency is uncommon. To date, there is no conclusive evidence that we should modify our currently high level of consumption of cow's milk.

1. Introduction: cow's milk in the dock

For many years, cow's milk has been vociferously accused of harming human health. This hostility is fed by a conspiracy theory suggesting that the dairy industry will go to any lengths to sell its produce and has bribed medical experts, scientific societies, and public health authorities into encouraging the consumption of milk. Milk, a complex food that has been consumed by humans in large amounts for millennia, is thus accused of causing numerous diseases that range from prostate and ovarian cancer to obesity, diabetes, multiple sclerosis, and otitis media. A study in women reported in 2014 found that cow's milk consumption was associated with excess mortality, osteoporosis, and fractures [1]. Processed dairy products and milk from other animals have largely escaped the animosity directed at cow's milk.

The arguments used to militate against cow's milk are drawn from eclectic sources ranging from philosophy and ethics to speciesism and science. Some can be immediately discarded as irrational, although popular and seductive, for instance, the notion that cow's milk is intended for calves and not for humans, that humans started drinking milk only a few thousand years ago, that humans are the only mammals that continue to drink milk after being weaned, and that Scandinavians have both the highest milk consumption and the highest incidence of hip fractures. These arguments are popularized in books, mainstream magazines, and the audio media.

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http://dx.doi.org/10.1016/j.jbspin.2016.06.006
1297-319X/

Here, we report a literature review that focused on potential effects of cow's milk on bone health in humans. Milk from other mammals is not discussed; hereafter, "milk" is designated as "cow's milk". Data on bone turnover and BMD are considered first, before a review of studies of the incidence of osteoporotic fractures.

2. Studies of bone turnover and BMD vs. studies of fractures: disturbing discrepancies

Humans have been consuming large amounts of milk for several thousands of years. The nutritional properties of milk are remarkable. Milk is an abundant source of calcium, whose bioavailability is high compared to other dietary sources, and the calcium/phosphate ratio in cow's milk is optimal for ensuring bone mineralization. The mean calcium content in whole and skim milk is 1150 mg/L, providing a ready means of meeting the daily requirement of 900–1200 mg. Milk is a well-balanced food, with powdered milk being composed of equal parts of protein, fat, and lactose.

A careful analysis of the scientific literature on milk and bone health uncovers a striking discrepancy: experimental and observational studies of surrogate markers (e.g., bone turnover markers and BMD) usually showed that milk consumption was associated with a slower pace of bone remodeling and a higher bone mass (Table 1). In contrast, studies that focused on osteoporotic fractures produced conflicting results, with some showing a protective effect of milk consumption and others no effect or an increase in the fracture risk (Table 2).

3. Milk consumption slows bone remodeling and protects bone mass in all age groups

In children and adolescents, who normally have a fast pace of bone turnover to meet the needs of skeletal growth, a high milk intake suppresses the secretion of parathyroid hormone (PTH) [2] and decreases the levels of bone resorption markers, while enhancing bone growth, whereas a high intake of meat does not share these effects [3]. In healthy postmenopausal women, milk supplementation also lowers the levels of bone turnover markers [4–6]. The effect of milk or any other source of calcium in slowing bone turnover is particularly marked in populations where the dietary calcium intake is low, such as elderly individuals in Asian countries [2,7–10].

In many countries, the consumption of milk as an abundant source of calcium and protein is encouraged during adolescence to optimize peak bone mass. In many observational studies, milk intake was associated with greater bone accretion as assessed based on BMD, both in Asia [11] and in the West [12,13], and with significantly higher levels of insulin-like growth factor (IGF) and growth hormone [12]. BMD correlates positively with milk protein intake, perhaps due to the ability of protein to increase the intestinal absorption of calcium [14]. Protein from low-fat milk is more beneficial to femoral neck bone mass compared to protein from red meat or processed foods [15].

In postmenopausal women, BMD correlates positively with milk intake during childhood and adolescence [16–21]. In older individuals, a diet high in low-fat milk was associated with bone mass preservation [15]. As with children and adolescents, the effect of milk intake in individuals older than 50 years is greatest in populations whose diet is low in calcium, for instance in Asia [7,8,22] and Poland [21].

Interventional studies of milk intake are methodologically more robust than case-control studies. They are few in number, however, and focused on postmenopausal women, in whom milk intake prevented bone loss at specific sites [22–26].

Metabolic syndrome may be associated with stronger protective effects of milk calcium in postmenopausal women aged 65 ± 5 years [27]. One possible explanation involves the production of incretins related to metabolic syndrome, as incretins have anabolic effects on bone.

4. Whey: a side-product with pivotal effects?

The benefits of milk are chiefly mediated by calcium and proteins, such as casein. Other components may also have favorable effects on bone, however. Several studies, many conducted in Asia, looked at the effects of whey protein on bone. Whey is the liquid left after curdled milk is strained. In mice, whey proteins diminished bone turnover [28], increased BMD and mechanical strength of the femur [29] and possibly promoted fracture healing [30]. Whey protein intake increased lumbar spine BMD in postmenopausal women [26] and lean mass in older women [27]. In mice, in vitro and in vivo studies demonstrated that bovine angiogenin purified from milk basic protein (MBP), a constituent of whey, strongly inhibited osteoclast activity [31]. Bovine angiogenin impaired F-actin ring formation and diminished the levels of mRNA for TRAP and cathepsin K, which are crucial to the bone-resorption effect of osteoclasts. Further work is warranted to evaluate these effects.

5. Milk and fractures: a jumble

Findings from epidemiological studies are not always consistent with those of surrogate endpoints such as bone turnover markers and BMD. Several obstacles exist to the demonstration of effects in epidemiological studies. One is the large number of interactions among nutrients in populations that are not always calcium-deficient. Another is the challenge raised by measuring food intakes, particularly retrospectively, which introduces multiple sources of bias. The occurrence of a fracture is a reliable endpoint that is fairly easy to collect in epidemiological studies, as there is usually a medical intervention and sometimes a hospital admission, at least for appendicular fractures. However, the occurrence of a fracture is difficult to interpret, as it is related not only to the characteristics of the bone tissue, but also to the existence of risk factors for falls. Interventional trials of milk intake with fracture occurrence as the primary endpoint (as done for osteoporosis drugs) would be extremely difficult to conduct, and none has been reported to date. A few case-control studies have been published. Most of the data, however, come from vast observational cohort studies that can detect statistical associations but are unable to demonstrate causality. Only a double-blind randomized controlled design can prove a causal link between milk intake and fracture risk. A randomized trial with no placebo evaluated the effects of milk powder supplementation for 2 years in postmenopausal Chinese women [7,32]. Fractures occurred in 3 of the 90 control women compared to 1 of the 95 supplemented women. This difference was not statistically significant. However, the trial was designed to assess changes in BMD and bone turnover; it was not powered to detect a difference in the fracture risk.

In children, milk intake was associated with a decreased risk of childhood fractures in some studies [33–35] but not in others [36,37]. A low milk intake during childhood was associated with a 2-fold increase in osteoporotic fractures in adulthood [20]. MEDOS is a case-control study of women in Mediterranean countries aged 50 years or over [38]. Higher milk intake was associated with a lower risk of hip fracture. However, this association may have been related to confounders, as women with a low milk intake more often had risk factors for fractures such as younger age at menopause, less physical activity, and heavier smoking. In individuals older than 68 years in the Framingham cohort, drinking more