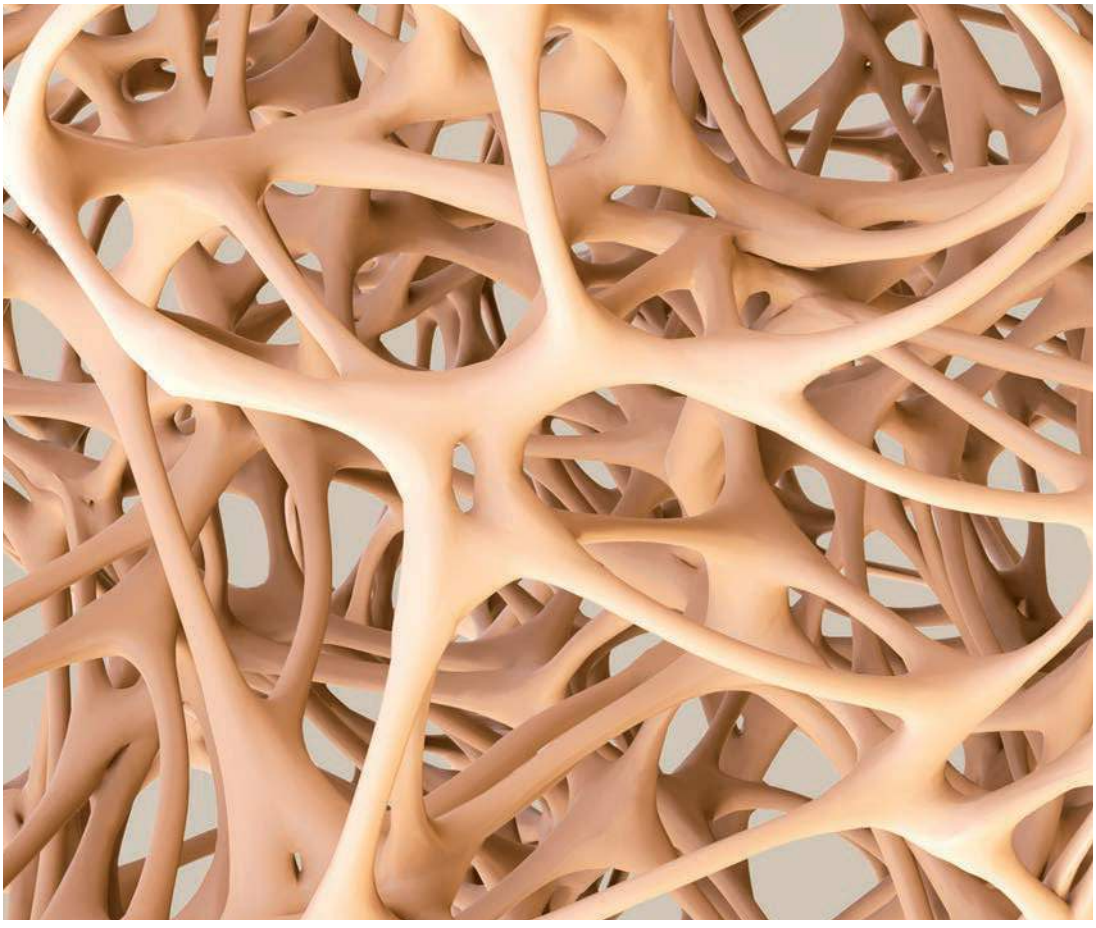
Bone health

The role of calcium in building and maintaining healthy bones is well established, and dairy foods are recognised as important sources of calcium, supplying up to two thirds of intake in the European diet. However, milk and dairy foods also contain other nutrients needed for bone health including protein, phosphorus and potassium (and vitamin D in the case of fortified dairy). Increasingly, the science indicates that nutrients in the dairy matrix work together to help maintain healthy bones. For example, there is some evidence that milk's calcium may offer longer lasting skeletal benefits than supplements due to its favourable calcium-phosphorus ratio, and that the calcium and protein in dairy have positive interactions on bone health.



Dairy and bone health in children and adolescents

Both observational and intervention studies provide evidence linking dairy consumption with bone health, especially in children and adolescents [1-3]. In children, a meta-analysis of studies investigating the effect of dairy products and dietary calcium (predominantly from dairy) on bone mineral content (BMC) reported that total body and lumbar spine BMC were significantly greater in children with higher intakes[4]. Dairy as part of an overall healthy dietary pattern has also been associated with beneficial effects on bone development[5]. Intervention studies which have specifically used milk or dairy foods are limited compared with those for calcium supplements, but positive effects have been reported; including in French, Finnish and British children[6-8]. For example, significant improvements in bone mineral acquisition compared to control subjects were observed in adolescent British girls who were given 568ml (one pint) of milk a day for 18 months[8]. The corollary is that milk avoidance in children has been associated with increased risk of fracture and poorer bone health[10,11]. In a 2016 position statement on lifestyle choices that promote maximal bone health from childhood through adolescence, the National Osteoporosis Foundation concludes that there is 'good evidence' for a role for dairy consumption (the 'best evidence' is for the positive effects of calcium intake and physical activity)[12]. A number of retrospective studies, although not all, have found that milk consumption in childhood and adolescence is related to better bone health and / or reduced risk of fracture later in life[13]. There are limitations to such studies, however, including accurate recall of childhood milk and dairy intake.

Dairy and bone health in adults

For adults, the majority of observational studies report either a positive association between milk and milk products and BMC or bone mineral density (BMD) or a neutral outcome [1,2]. Again, randomised controlled trials using milk and dairy foods are limited compared with calcium supplementation ones, and longer-term trials and meta-analyses are needed. In such studies the outcome will depend on factors such as the age of the subject, relation to the menopause for women, initial dairy intakes and so on[13]. Intervention studies have, however, reported positive associations between increase in dairy food intake and BMC or BMD, and reductions in bone turnover markers[14,15]. On the whole, there is support for favourable effects of dairy on measures of bone health in adults[3].

Fracture risk

With respect to fracture risk, the effects of dairy are less clear. This may be due to heterogeneity in the study designs, duration, participants' age, and other confounding factors such as vitamin D status and physical activity. A meta-analysis of prospective cohort studies published in 2011, found no overall association between adult milk intake and hip fracture risk in women; insufficient data was available in men[16]. However, the data on women were disproportionately influenced by one study from Sweden; when the authors excluded this study from the analysis there was a marginally significant 5% lower hip fracture risk for each glass of milk consumed per day. A subsequent publication in 2014 utilising data from the same Swedish cohort of 61,000 women but with a longer follow up (around 20 years) found fermented milk products (yogurt and other soured milk products) and cheese consumption were associated with a significant decrease in fracture incidence[17]. However, high intakes of milk (three or more glasses/day; more than 600 ml/day) were associated with increased fracture rate. It is worth noting that when the dietary questionnaires were performed (1987–90 and 1997) milk in Sweden was fortified with high dose of

vitamin A: such levels of vitamin A intake have been linked to an increased risk of fracture. A study of Finnish women has reported that milk avoidance (because of lactose intolerance) was associated with increased fracture risk[18].

No dairy intervention trials on fracture risk are available because of the feasibility of carrying out such a study; however, calcium supplementation trials do exist. A meta-analysis of 17 randomised trials concluded that calcium supplementation (with or without vitamin D) decreases fracture risk by 12% in people aged 50 years and older[19]. The fracture risk reduction was greater (24%) in trials when compliance was high; also in participants older than 70 years and whose daily calcium intake was initially low.

Potential dairy matrix mechanisms

The importance of calcium in bone development and maintenance is well established [1,13]. Milk and milk products make the largest contribution to calcium intake in the European diet. Few other foods naturally contain as much calcium, and dairy sources are some of the most bioavailable[20]. While it is sometimes assumed that supplementation with the same amount of calcium from different sources - e.g. milk, foods fortified with calcium and calcium supplements – have comparable effects on bone health, there is some evidence of a beneficial 'dairy matrix effect'[21]. Dairy foods may have greater benefits than the equivalent calcium in the form of supplements. In adolescent girls, for example, it has been estimated that bone mineral density increases by up to 10% when 700mg extra calcium is provided as dairy foods, compared with an increase of 1% to 5% when the same quantity of calcium is given as a supplement[22]. Similarly, using cheese to increase calcium intake in 10- to 12-year-old Finnish girls resulted in a greater increase in bone mineral density compared to either a calcium supplement or a calcium plus vitamin D supplement[7]. Another randomised controlled trial investigating the effect of dairy products providing 1,200mg calcium a day or an equivalent calcium supplement on markers of bone metabolism and BMD found that after 12 months, the dairy intervention group had greater improvements in pelvis, spine and total BMD than the calcium supplement group[14].

The greater benefits of dairy may be due to the presence of other nutrients in the dairy matrix which are important for bone health such as protein and phosphorus, and their interactions with calcium. Protein is essential for bone development in children and is needed for the maintenance of normal bones in adults since amino acids are required for the synthesis of intracellular and extracellular bone proteins. Older adults consuming a protein-restricted diet are at higher risk for bone loss and fractures, and sufficient protein intake is recommended in guidelines for maintaining skeletal health[23-26]. There has been some controversy around the adverse effects of high protein intakes, but it is now established that although a high-protein diet increases urinary calcium excretion this does not result in a negative skeletal calcium balance, or bone loss[24-28]. Indeed, recent research suggests higher protein intakes are beneficial to bone health, especially when calcium intake is also adequate[29]. For example, in the US Osteoporotic Fractures in Men study, greater intakes of dairy protein were associated with a decreased risk of hip fracture[30]. Similarly, in healthy postmenopausal women, dairy protein intakes were positively associated with measures of bone strength and microstructure[31]. The potential mechanisms for this include protein enhancing calcium balance by stimulating intestinal calcium absorption, both directly and indirectly via an IGF1-vitamin D link. Part of the explanation of the greater effectiveness of dairy calcium versus supplements may also be due to better absorption of calcium because of the presence of lactose and / or casein phosphopeptides in the dairy matrix[7]. Fermented dairy products may additionally enhance calcium absorption through positive alterations in the gut microbiota[32].

In addition to potentially larger effects, it has been suggested that the skeletal benefits of dairy calcium may persist longer than from calcium supplements [25]. In a study of 8-year-old French girls, the benefits of milk-extracted calcium phosphate on bone mass remained 3.5 years post supplementation[4]. This has not been the case after supplementation with calcium salts (such as citrate malate or carbonate). Part of the explanation may lie in the favourable calcium to phosphorus ratio in milk. Phosphorus (as inorganic phosphate) is an important structural component of bone and an adequate intake is necessary for bone growth and development, and the maintenance of normal bones in later life[24]. Although a high intake, if accompanied by low calcium (in a ratio of about 4:1) may be deleterious to bone, the phosphorus to calcium ratio of milk (0.8:1) can enhance calcium balance by stimulating renal tubular reabsorption of calcium and lead to positive effects on bone[33].

Other nutrients in milk and dairy foods are also involved in bone health including magnesium, potassium, vitamin K2 and zinc, as well as vitamin D in fortified dairy[1]. Increasingly, the science indicates that the nutrients in the dairy matrix may work together to help maintain healthy bones. Simply in terms of the quantities of 'bone' nutrients in dairy, however, it has been suggested that it is difficult to devise a diet that is 'bone healthy' without including three servings of dairy a day [1].