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This review summarises contemporary research regarding the association between dairy intake and bone health, commenting on the effect of lifestyle and nutrition in maintaining skeletal health.

A publication for health professionals

Dairy *for bone health*

Bone health is a multifactorial muscular–skeletal matter, with many outcomes having been used in its assessment. These include peak bone mass (which take into account bone strength, mass, microarchitecture and repair),[1] fractures, total-body bone mineral content, bone mineral density (either across the total body or in the hip or femoral head) and markers of bone turnover.[2]

Non-modifiable factors that increase the risk of bone loss include genetics, being female and of European or Asian descent (compared to being an African American or Hispanic woman), maturation and having a small body build. Modifiable lifestyle factors such as physical inactivity or excessive exercise, weight loss approaches that do not include exercise,[3] underweight and anorexia nervosa,[4] smoking, use of certain medications and nutrition can affect 20–40% of adult peak bone mass.[1]

With regard to the role of nutrition in bone health, many diets, food patterns, foods and nutrients have been considered. The micronutrients classically associated with bone health are calcium and vitamin D, with magnesium, manganese, zinc, vitamin K, phosphorus and the calcium : phosphorus ratio having been added to the list recently.[1,5] The contribution of fat and protein to bone health has also been studied.[1,6]

As these nutrients all form an intrinsic part of dairy, which, as food group, is included in dietary patterns associated with bone health,[7] an investigation into the link between bone health and nutrition cannot exclude the role of dairy products. All the dairy products mentioned in the South African food-based dietary guidelines are rich sources of the key nutrients involved in skeletal integrity[8] and in some cases specific dairy foods (e.g. fermented milk products) may contain pre- or probiotics capable of modifying intestinal calcium absorption or bone metabolism.[9]

This review therefore serves to summarise pertinent contemporary research with regard to the association between dairy intake and bone health.

Micronutrient intake

Calcium and phosphorus

The importance of calcium for bone health is undisputed, highlighted by findings of a recent international prospective study that showed adequate calcium intake over the long term to reduce the risk of osteopenia in children.[10] As it is practically impossible to achieve calcium intake recommendations when dairy foods are excluded from the diet, the contribution of milk or dairy foods is closely linked to bone health.[8] A recent local study reported that low intakes of calcium and vitamin D, presumably due to low milk intake after weaning, contributed to stunting (a short height for age) among children.[11] Conversely, Marshall et al.[12] reported that higher longitudinal milk intakes during childhood and adolescence were associated with increased height: participants' height increased by 0.39 cm for each additional cup of milk consumed per day. In contrast, non-dairy milk intake is associated with lower childhood height.[13]

The close interplay between calcium and phosphorus has been called the 'bone health duet'. Adequate intake of calcium and phosphorus is in the approximate molar ratio of 1-2:1 (Ca:P).[14]

Magnesium

The link between magnesium intake and bone mineral density and fracture risk is controversial. Previous studies showed that although magnesium deficiency affects skeletal health negatively, intake of amounts greater than the recommended dietary allowance may also pose risks. Some reports also highlighted bone lesions and lower bone mineral density in cases of acute exposure to high-dose magnesium, but according to Orchard et al.[15] there are no definitive data to support a link between chronic excess magnesium intake and reduced bone mineral density and fracture risk. A systematic review and meta-analysis[16] further concluded that high magnesium intakes were not significantly associated with increased risk of hip or total fractures, as only a marginally positive correlation was found for total and femoral-neck bone mineral density, and a non-significant correlation for bone mineral density in the lumbar spine.

Protein intake

Protein has a crucial role in maintaining skeletal muscle mass throughout life and in the absence of detrimental effects on bone health, adequate protein intake (0.8 g/kg/day or 10–15% of energy intake) throughout life remains an important dietary recommendation for skeletal health.[2,6]

In adults, 1–8% of the variance in bone mineral density and content can be explained by dietary protein intake,[8] compared with 7–21% in children.[6] Curneen et al.[17] further concluded that increased protein intake among the elderly reduces bone-related morbidity and mortality in this group, although Darling et al.[6] noted no association between protein intake and the relative risk for osteoporotic fracture. In a systematic review of studies that investigated protein intake for bone health,[1] four of five prospective studies pointed to positive findings, whereas a randomised controlled trial concluded a null result.

Epidemiological studies further suggest that long-term protein intake above the current recommended dietary allowance is linked to favourable bone mineral density and a lower risk of bone fracture incidence, possibly owing to amino acid availability for bone-matrix collagen synthesis, increased serum insulin-like growth factor levels[1] and reduced serum

parathyroid hormone levels.[2,18] Although concern has been raised that the acid load resulting from the metabolism of S-amino acids during high protein intake reduces renal reabsorption of calcium and increases urinary calcium excretion, such diet-induced acidosis can be offset in a diet that includes adequate calcium, vitamin D, fruit and vegetables.[18]

With regard to the role of protein source in bone health, a systematic review and meta-analysis by the US National Osteoporosis Foundation showed no differential effect between soy and animal proteins.[2,19] In contrast, a study on postmenopausal women showed that intake specifically of animal and dairy protein had a beneficial effect on bone strength and microstructure.[20]

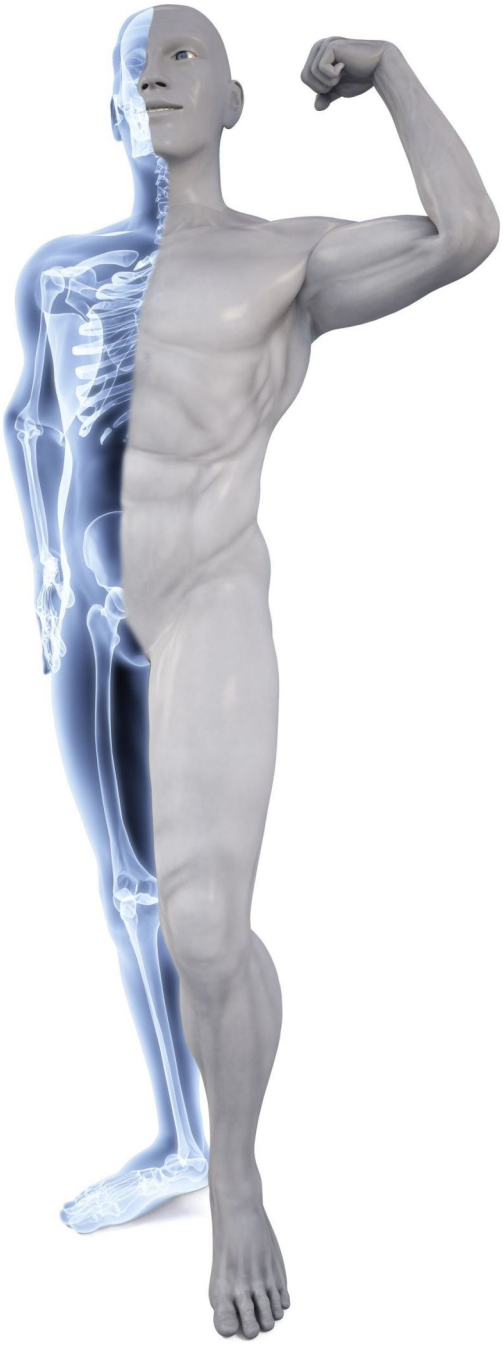
Integration

Eighteen modifiable lifestyle factors were systematically reviewed by the US National Osteoporosis Foundation with regard to their association with peak bone mass.[1] Of these, calcium intake and physical exercise received an 'A' grading, reflecting the highest level of evidence for association. Intake of dairy and vitamin D received a 'B' rating, pointing to 'good' evidence. Smoking and intake of protein, fibre, fruit and vegetables, and sugar-sweetened beverages all received a 'C' rating, suggesting 'limited evidence' for an association with peak bone mass at this stage. Research on the remaining lifestyle factors was deemed 'inadequate' and they were subsequently graded 'D'.[1]

In response to a controversial study by Michaëlsson et al.,[21] other major systematic reviews and meta-analyses have been conducted. One such study pooled information from 10 cohort and eight case–control studies.[22] With hip fracture as end point, this analysis showed the intake of yoghurt and cheese to be significantly associated with lower risk in cohort studies. A review by Händel et al.[23] showed factors such as milk avoidance, high energy intake, high cheese intake, high intake of sugar-sweetened beverages and no breastfeeding to emerge as predictors for fractures in early life and childhood.

Conclusion

Osteoporosis has been called 'a paediatric disease with geriatric consequences'. The prevention of this condition, and particularly of osteoporotic bone fractures, will result in a major reduction in healthcare costs and personal suffering. Although many factors need to be considered in interpreting the effect of lifestyle and nutrition on bone health, the role of dairy intake throughout life is undisputed. Current evidence suggests that dairy contributes to bone health either as part of a bone-promoting dietary pattern or by functioning as a vehicle for delivering key nutrients embedded in a matrix that supports optimal skeletal integrity throughout life.



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