

Calcium and bone health: position statement for the Australian and New Zealand Bone and Mineral Society, Osteoporosis Australia and the Endocrine Society of Australia

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This position statement reviews the evidence relating to bone health and total calcium intake from food as well as calcium supplementation. The consensus process used in developing the statement is summarised in Box 1. The statement discusses current evidence on the role of calcium throughout the different stages of life in relation to fracture risk, but also with respect to other endpoints such as bone density, particularly where evidence of fracture endpoints is lacking. It provides general practitioners and physicians with a summary of key evidence-based points (Box 2) and a consensus of expert opinion on the role of calcium in bone health (Box 3).

Calcium, bone and vitamin D

Calcium deficiency leads to a reduction in bone mass by increasing bone resorption to preserve the level of ionised calcium in the extracellular fluid. Dietary calcium deficiency may also be a major cause of rickets in children in developing countries. The integrity of the system depends critically on vitamin D status. There is an interaction between dietary calcium deficiency and vitamin D deficiency such that vitamin D-replete individuals may be relatively vitamin D-deficient in the presence of a low-calcium diet, and vitamin D deficiency may exacerbate dietary calcium deficiency through reduced gastrointestinal absorption of calcium.⁴ Secondary hyperparathyroidism and increased bone resorption occur in both calcium and vitamin D deficiencies.

The growing skeleton

Kinetic studies of adolescent girls have shown that calcium retention is greatest when the growth spurt is at its peak (in early puberty).⁵ These observations have encouraged efforts to maximise peak bone mass through calcium supplementation during skeletal growth. However, clinical, longitudinal, retrospective and cross-sectional studies in children show inconsistent findings regarding calcium intake and bone changes.⁶ Results of the studies are influenced by baseline calcium intake, stage of development, and the sites evaluated for bone mineral density (BMD). When baseline habitual calcium consumption is low, larger increments in BMD occur with increased dietary calcium intake,⁷ and sustained beneficial effects of higher intake are more likely to occur in individuals with previously low habitual calcium intake.⁸ In a 3-year randomised controlled trial (RCT) of calcium supplementation, a positive effect on BMD was observed in prepubertal twin pairs but not pubertal or postpubertal twin pairs.⁹ In contrast, Nowson and colleagues demonstrated increased spine and hip BMD in postmenarcheal twin pairs.¹⁰

Most,¹¹ but not all,¹² RCTs involving children and adolescents using either dairy-supplemented foods or calcium supplementation have demonstrated some benefit at one or more of the BMD sites measured. Nevertheless, a recent meta-analysis¹¹ showed that although the point estimates for 19 RCTs were positive in favour of

ABSTRACT

- This position statement was prepared by the Working Group of the Australian and New Zealand Bone and Mineral Society and Osteoporosis Australia. The final statement was endorsed by the Endocrine Society of Australia.
- Currently, the balance of evidence remains in favour of fracture prevention from combined calcium and vitamin D supplementation in elderly men and women.
- Adequate vitamin D status is essential for active calcium absorption in the gut and for bone development and remodelling.
- In adults with a baseline calcium intake of 500–900 mg/day, increasing or supplementing this intake by a further 500–1000 mg/day has a beneficial effect on bone mineral density.
- Calcium intake significantly above the recommended level is unlikely to achieve additional benefit for bone health.

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benefit, the confidence intervals usually crossed zero. There was no effect on BMD in children at the femoral neck or lumbar spine, and only a small benefit on total body BMD and upper limb BMD that was unlikely to substantially reduce adult fracture risk. The upper limb was the only site where a sustained BMD benefit was demonstrated after cessation of calcium supplementation.¹¹ More studies are required in children with low calcium intakes and in peripubertal children.

1 The consensus process

This position statement was developed by a Working Group* commissioned by the Australian and New Zealand Bone and Mineral Society (ANZBMS) and Osteoporosis Australia (OA). All members of the Working Group have published extensively in the field of osteoporosis and have a particular interest in the role of calcium. Specific expertise includes endocrinology (I R R, M A K), nutrition (C A N, K M S, A D) and exercise (K B). The Working Group prepared an initial evidence-based draft statement that was circulated for comment to senior colleagues in clinical bone research within Australia. The statement was subsequently modified and all members of the ANZBMS were notified by email that a draft statement had been posted on the ANZBMS website for widespread comment and feedback. Suggested revisions were incorporated with consensus from the Working Group. The scientific affairs committees of the ANZBMS and OA reviewed the final manuscript. This edited version of the full position statement has been reviewed by all members of the Working Group and senior representatives of OA and ANZBMS.

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2 Key evidence-based points*

The available data suggest that:

- Supplementation with calcium plus vitamin D prevents fractures in frail elderly people, particularly women in residential care (Level I).
- Inadequate vitamin D status exacerbates the deleterious effects of low calcium intake (Level II).
- Early puberty is likely to be an ideal time to ensure adequate calcium intake in order to maximise bone health in the growing skeleton (Level II).
- The requirement for calcium during pregnancy and lactation is no greater than that required during the non-pregnant state, except in teenagers (Level II).
- Foods high in calcium provide protein and other micronutrients that may be important for general health, particularly in frail elderly people (Level I).
- Long-term adherence to calcium supplementation is poor. This is possibly related to digestive problems, constipation, and/or the cost to the individual (Level II).
- Calcium intake and weight-bearing exercise can have an additive effect in improving bone health (Level II).

*Based on National Health and Medical Research Council levels of evidence.¹ ◆

Calcium intake appears to explain only a small proportion (1%–5%) of the variance in adolescent bone gain and later peak bone mass.¹³ Although there are longitudinal data linking calcium intake to skeletal accrual of calcium, the effect size appears to be small and a positive association is not consistently found.^{14,15} An association between childhood fracture and calcium intake has been reported: peripubertal boys and girls who had sustained a fracture had lower calcium intakes than those with no fracture history.¹⁶ However, an association between fragility fractures in older age and calcium status in childhood is difficult to establish.

The recommended dietary intake (RDI) of calcium for children and adolescents in Australia and New Zealand is 1000–1300 mg/day, and the estimated average requirement (EAR) is 800–1050 mg/day.* For children with very low calcium intakes, either by choice or because of intolerance to dairy products, dietary modification or calcium supplementation is advisable.

Reproductive years, including pregnancy and lactation

Pregnancy and lactation are characterised by physiological adaptive processes that provide the calcium necessary for fetal growth and breastmilk production, independent of maternal calcium intake.¹⁸ The patterns of change in calcium and bone metabolism during pregnancy and lactation are consistent with the mobilisation of calcium from the maternal skeleton to meet the high requirement for fetal growth towards the end of gestation and for breastmilk production during lactation, with subsequent restoration in the later stages of lactation and after weaning. However, the skeletal effects of pregnancy and lactation appear to differ in mothers who are under 21 years, and the calcium requirement is higher for pregnant and lactating teenagers.¹⁹

*The RDI meets the needs of 98% of the population, and the EAR meets the needs of 50% of the population. The National Health and Medical Research Council publishes nutrient reference values, a set of recommendations for nutritional intake based on currently available scientific knowledge.¹⁷

Reductions in bone mineralisation associated with lactation are reversible, and by 3 months after weaning there is little to distinguish mothers who have breastfed from those who have not, including those who have breastfed for an extended period. Furthermore, parity and lactation do not appear to be associated with increased fracture risk.²⁰ Calcium concentration in breastmilk is not influenced by maternal calcium intake, and lactational performance does not appear to be impaired in women who have a low calcium intake.²¹ However, among women whose dietary calcium is low, increasing calcium intake during pregnancy to meet the RDI of calcium may be associated with skeletal benefits in the newborn.²²

The RDI of calcium in Australia and New Zealand for women aged between 19 and 50 years is 1000 mg/day and the EAR is 840 mg/day. For teenage pregnant or lactating women, the RDI is 1300 mg/day and the EAR is 1050 mg/day.

Adulthood

Although there is some evidence that calcium supplementation is beneficial for men and for young women before menopause, most research has focused on postmenopausal women. There is little evidence relating to the effect of calcium on the bone health of men aged under 50 years.

Bone mass remains relatively stable during early adulthood and up to the age of about 50 years (in men) or menopause (in women). For about the first 5 years after menopause, women lose bone at the rate of about 2%–3% per year and then continue to lose about 1% of bone mass per year to the end of life. During this time, there is a decline in intestinal calcium absorption and an increase in urinary calcium excretion. Men also start to lose bone at about the age of 50 years, but more slowly than women. The rate of bone loss in men and women over the age of 60 years is about the same, and calcium absorption decreases with age.

RCTs assessing BMD generally show a beneficial effect of calcium treatment in both men and women (typically a 1%–2% absolute difference between the treatment and control groups over 2–3 years).^{23–27} This results in a sustained reduction in bone loss of 50%–60%.^{23–26} Benefits of calcium treatment are more consistent in late postmenopausal women than in perimenopausal women, perhaps because of greater variation in the rate of bone loss among perimenopausal women. However, a calcium intervention trial that divided women into those aged above and below 60 years revealed no difference in BMD change with calcium treatment.²³ As with

3 Key recommendation

Randomised controlled trials show that, in people with a baseline calcium intake of 500–900 mg/day, increasing the intake by a further 500–1000 mg/day has a beneficial effect on bone mineral density (BMD).

The effect of calcium supplementation on bone health is modest, as shown by increases in BMD and reductions in excessive bone turnover. The relative risk reduction for osteoporotic fracture is likely to be no more than 10%–20%. There is little evidence with fracture endpoint in men.^{2,3}

Although inadequate calcium intake is likely to be deleterious to bone, calcium intake significantly above the recommended level is unlikely to achieve additional benefit for bone health. Thus, strategies to increase calcium intake should be focused on people whose calcium intake is lowest. ◆

children and adolescents, the effects of calcium treatment appear to be greater among women whose baseline dietary calcium intake is low.^{23,28}

Even among women with high calcium intakes, there is a transient increase in BMD over the first year of calcium supplementation.^{29,30} This is attributed to the suppression of circulating parathyroid hormone. The more sustained and cumulative benefit in cortical bone may reflect the slower turnover of cortical bone, but probably also implies a sustained positive effect of calcium supplementation on bone balance.

RCTs of calcium supplementation in older adults with fracture as the endpoint have suggested that there is some reduction in fracture risk in subjects receiving calcium, even though between-group differences in absolute BMD are modest.^{29,31,32} The commonly reported moderate-to-low compliance (80% or more of study tablets taken by 50%–58% of subjects)^{2,23–26,33} in studies using daily calcium supplements is likely to limit their effectiveness as a public health intervention.^{2,3} Although a per-protocol analysis of 1500 older Australian women suggested that calcium supplementation (1200 mg/day) reduced the risk of clinical fracture by 34%, no significant effect was reported in the intention-to-treat analysis.² Comparable results have been reported from a similar New Zealand study.³⁴ However, recent data suggest that hip fracture risk may not be reduced with calcium supplementation, and in fact an increased risk is possible.^{34,35}

In a landmark 3-year study by Chapuy and colleagues, more than 3000 institutionalised women aged 69–106 years were randomly allocated to receive either a placebo or 1.2 g elemental calcium plus 800 IU vitamin D daily.³⁶ Low baseline serum levels of 25-hydroxyvitamin D were normalised by the intervention, and non-vertebral fractures and hip fractures were reduced by 24% and 29%, respectively ($P < 0.001$). The reductions in absolute fracture rates were 1.9% for non-vertebral fractures and 1.4% for hip fractures. The relative contributions of vitamin D and calcium supplementation to reducing fracture risk are unclear. Some studies,^{37–40} but not all,^{33,36} have duplicated these results. Variation between groups in baseline vitamin D status would at least partially explain the heterogeneity of responses to calcium and vitamin D supplementation. A more detailed discussion regarding vitamin D and skeletal health can be found in the Australian and New Zealand Bone and Mineral Society's position statement on vitamin D.⁴¹

The balance of evidence remains in favour of fracture prevention from combined calcium and vitamin D supplementation in elderly men and women.³ Furthermore, clinical trials of antiresorptive therapies have looked at fracture risk in participants treated with the active agent plus calcium compared with placebo plus calcium. Thus, calcium supplementation is currently regarded as an integral component of antiresorptive regimens.

Food sources and interaction with other dietary components

Calcium is predominantly found in dairy foods, but smaller amounts are found in bony fish, legumes, certain nuts, and calcium-fortified soy beverages or breakfast cereals. Low-fat options can also be a good source of calcium and are a preferable choice for many people. The calcium content of common foods can be accessed in the guide for GPs produced by Osteoporosis Australia.⁴²

Some dietary constituents can impair calcium bioavailability by forming insoluble calcium complexes.⁴³ These substances include phytates (found in cereals, bran, soybean and seeds) and oxalates (found in spinach, rhubarb and walnuts). Some vegetarian diets may therefore adversely affect calcium balance, particularly if the calcium content is low because of avoidance of dairy products.⁴³

Sodium is an important determinant of urinary calcium excretion. A high salt intake has been associated with lower bone mass in some but not all studies.

Evidence exists for beneficial effects of both low and high protein intakes.⁴⁴ Although an adequate protein intake is important to support bone growth in children and maintain bone mass in older adults, higher intake of protein, particularly animal protein, may be associated with increasing urinary calcium losses. However, the benefit of additional calcium from dairy products outweighs the possible deleterious effects of extra protein.⁴⁵ High-calcium foods such as dairy products contain a range of other essential nutrients, and calcium-fortified soy products can be used as a substitute when necessary. However, there is little evidence that the small amounts of various mineral and vitamin additives present in some marketed calcium supplements improve their effectiveness.

Adequate vitamin D status is essential for active calcium absorption in the gut and for bone development and remodelling. Consequently, adequate vitamin D status should be established, particularly in older patients requiring calcium supplementation. Vitamin D supplementation in doses less than 400 IU per day is unlikely to have a significant effect on bone health, and people aged over 70 years require doses of more than 600 IU per day to affect their bone status.

For women aged 19–50 years and men aged 19–70 years, the RDI for calcium is 1000 mg/day and the EAR is 840 mg/day. The RDI increases to 1300 mg/day for women over 50 years and for men over 70 years. However, it is difficult for many older adults to achieve a dietary intake of 1300 mg/day, as many eat only small quantities and are on low-energy intakes. On a “usual Australian diet”, people derive 60% of their dietary calcium from dairy products. Those who avoid dairy products need to ensure that substitute food products are calcium-fortified. To achieve a daily intake of 1000–1300 mg calcium, at least three serves of dairy per day are recommended, with at least one of those being calcium-fortified. For people who do not consume dairy products, calcium-fortified soy products (eg, soy milk) provide similar amounts of calcium.

Interaction with exercise

The beneficial effects of weight-bearing physical activity and calcium intake are additive.⁴⁶ It is thought that exercise produces region-specific effects, whereas higher calcium intake produces a more generalised effect in addition to the benefits of exercise.⁴⁷

Types of calcium supplementation

Although calcium intake can be increased by dietary means, long-term adherence to high-calcium diets is poor. Calcium supplements are a useful way of helping people who are unable to derive sufficient calcium from dietary sources. The ability to adapt to low-calcium diets and intestinal calcium absorption deteriorates with age. An extra 500–1000 mg elemental calcium per day will usually suffice for most people. When checking the true calcium content

of foods and supplements, it is the elemental calcium that matters. As calcium carbonate requires an acid environment to dissolve and calcium citrate does not, the latter supplement is preferable for people with achlorhydria and those taking medications that inhibit gastric acid secretion.

There is some evidence that taking calcium supplements in the evening may work to advantage by suppressing the nocturnal rise in bone resorption, but it has also been suggested that divided dose regimens (one-third in the morning, two-thirds in the evening) may lead to a greater total calcium absorption.⁴⁸

Calcium supplements should be given with bisphosphonates and selective oestrogen receptor modulators (SERMs) as therapy for established osteoporosis.⁴⁹⁻⁵² The efficacy of bisphosphonate and SERM therapy in fracture prevention in the absence of calcium supplementation is unknown. It is critical that calcium and oral bisphosphonates be taken several hours apart, as calcium binds with these medications and prevents their absorption.

Calcium supplements are generally well tolerated and do not have major effects on the absorption of other micronutrients. Occasional adverse effects include constipation, bloating and flatulence. Changing preparations (eg, from calcium carbonate to calcium citrate) may alleviate some gastrointestinal side effects. Calcium supplementation is contraindicated in the presence of hypercalcaemia or marked hypercalciuria. Patients with calcium malabsorption associated with renal disease should seek specialist advice. The common practice of using calcium supplementation for phosphate binding in patients with renal impairment may contribute to the increased risk of cardiovascular disease in this population,⁵³ and a similar increase in risk has recently been reported in normal postmenopausal women.⁵⁴ If this finding is confirmed, a total reappraisal of the use of calcium supplementation in older people will be required.

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Competing interests

Ian Reid has been a consultant to Fonterra in the past.

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