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Building healthy bones throughout life: an evidence-informed strategy to prevent osteoporosis in Australia

The burden of osteoporosis in Australia

Osteoporosis imposes a tremendous burden on older Australians and their families, the health and social care systems and the national economy. This chronic disease affects 1.2 million Australians and another 6.3 million have osteopenia, meaning that their bone density resides in the range between the normal and osteoporosis.¹ Osteoporosis is manifested clinically in the form of fragility fractures, which are fractures resulting from low trauma, such as a fall from standing height. During the 2007–08 financial year, almost 82 000 individuals in Australia were hospitalised with fragility fractures,² including >17 000 cases of hip fracture.³ In the 2000–01 financial year, the total direct care cost of osteoporosis was estimated to be \$1.9 billion per year, with an additional \$5.6 billion expended on indirect costs. The New South Wales Agency for Clinical Innovation reported that 35% of minimal trauma fracture admissions from 2002 to 2008 presented to hospital with a refracture.⁴ These fractures accounted for 16 225 admissions, with an average length of stay of 22 days. While data on the costs of refractures in Australia are yet to be published, analysis from the United States reported a nationally projected annual cost of almost US\$2 billion.⁵

Policy, clinical guidelines and current standards of care in Australia

Osteoporosis was a focus of the Australian National Health Priority Area on musculoskeletal conditions and arthritis designated in 2002.⁶ The associated National Action Plan⁷ and National Service Improvement Framework⁸ highlighted a significant care gap, even among Australians who have already suffered fragility fractures. This is particularly surprising given that the Medicare Benefits Schedule⁹ and the Pharmaceutical Benefits Scheme¹⁰ make provision for care of such individuals. The departments of health for NSW,⁴ Western Australia¹¹ and South Australia¹² have published strategies that aim to improve the management of osteoporosis and close existing care gaps. The states' strategies would enable universal implementation of many of the recommendations made in the National Health and Medical Research Council (NHMRC)-approved osteoporosis guidelines published by the Royal Australian College of General Practitioners in 2010.¹³ As fragility fractures are usually the result of a fall, implementation of the Australian Commission on Safety and Quality in Health Care guidelines on falls prevention is an essential component of best practice in fragility fracture prevention.^{14–16}

Building healthy bones throughout life: an evidence-informed strategy to prevent osteoporosis in Australia

Both general practitioners and their patients often overlook bone health and, as a result, osteoporosis is often not diagnosed until fragility fractures occur. There is also a lack of an accepted strategy for osteoporosis prevention in Australia. Currently, treatment of individuals is based on either bone mineral density (BMD) measurement and/or a

Summary

- Osteoporosis imposes a tremendous burden on Australia: 1.2 million Australians have osteoporosis and 6.3 million have osteopenia. In the 2007–08 financial year, 82 000 Australians suffered fragility fractures, of which >17 000 were hip fractures. In the 2000–01 financial year, direct costs were estimated at \$1.9 billion per year and an additional \$5.6 billion on indirect costs.
- Osteoporosis was designated a National Health Priority Area in 2002; however, implementation of national plans has not yet matched the rhetoric in terms of urgency.
- *Building healthy bones throughout life*, the Osteoporosis Australia strategy to prevent osteoporosis throughout the life cycle, presents an evidence-informed set of recommendations for consumers, health care professionals and policymakers. The strategy was adopted by consensus at the Osteoporosis Australia Summit in Sydney, 20 October 2011.
- Primary objectives throughout the life cycle are:
 - to maximise peak bone mass during childhood and adolescence
 - to prevent premature bone loss and improve or maintain muscle mass, strength and functional capacity in healthy adults
 - to prevent and treat osteoporosis in order to minimise the risk of suffering fragility fractures, and reduce falls risk, in older people.
 - The recommendations focus on three affordable and important interventions — to ensure people have adequate calcium intake, vitamin D levels and appropriate physical activity throughout their lives.
- Recommendations relevant to all stages of life include:
 - daily dietary calcium intakes should be consistent with Australian and New Zealand guidelines
 - serum levels of vitamin D in the general population should be above 50 nmol/L in winter or early spring for optimal bone health
 - regular weight-bearing physical activity, muscle strengthening exercises and challenging balance/mobility activities should be conducted in a safe environment.

prior fracture. However, >50% of women and >70% of men who sustain fragility fractures do not have BMD in the osteoporosis range (T score <−2.5). This represents a “prevention paradox”, which is the basis for developing *Building healthy bones throughout life* — a population-based prevention strategy throughout the life cycle.

Osteoporosis has been described as a “paediatric disease with geriatric consequences”.¹⁷ In order to optimise bone health in the population and minimise incidence of painful, debilitating and costly fragility fractures among older people, a lifelong approach to building and maintaining a healthy skeleton is paramount. During 2011, Osteoporosis Australia — a not-for-profit organisation that is the premier national consumer body in the bone arena — undertook to develop a

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coherent, evidence-informed national strategy to realise its vision of healthy bones for all Australians.

The strategy intended to focus on three affordable and important interventions: to ensure people have adequate calcium intake, serum levels of vitamin D and appropriate physical activity throughout their lives. The draft strategy was prepared by national and international research leaders in bone health and was made available for public consultation. A revised and penultimate draft was put forward for further discussion and consensus at the Osteoporosis Australia Summit held in Sydney on 20 October 2011. The final version of *Building healthy bones throughout life* is available at mja.com.au. This article provides a précis of the extensive evidence base that was considered to develop the strategy and inform the recommendations for building and maintaining a healthy skeleton in children, healthy adults, and older adults and individuals with osteopenia and osteoporosis. In conclusion, the recommendations made in *Building healthy bones throughout life* to prevent osteoporosis in Australia are described.

Building healthy bones in children

The primary objective during childhood and adolescence is to optimise the individual's peak bone mass. Analytical modelling predicted the relative influences of peak BMD, age-related bone loss and menopause on the development of osteoporosis.¹⁸ A 10% increase in peak BMD was predicted to delay the development of osteoporosis by 13 years. Over the past century, life expectancy at birth has increased by nearly 40%, from 59 to 82 years for women and from 55 to 76 years for men.¹⁹ Accordingly, ensuring current and future generations of Australian children achieve peak bone mass, within their genetic potential, will play a vital role in the nation's bone health as the population continues to live longer.

Calcium needs in children

The NHMRC published *Nutrient reference values for Australia and New Zealand including recommended dietary intakes*²⁰ in 2006. The recommended dietary intakes (RDIs) for calcium for children by age are:

- 1–3 years: 500 mg/day;
- 4–8 years: 700 mg/day;
- 9–13 years: 1000–1300 mg/day;
- 14–18 years: 1300 mg/day.

The NHMRC also provided RDIs during pregnancy: 1300 mg/day and 1000 mg/day for mothers aged 14–18 years and 19–50 years, respectively. The estimated average requirements (EARs) which informed these RDIs were based on modelling that included a component for skeletal growth. The NHMRC noted the "striking increase in the rate of skeletal calcium accretion from 12 to 18 years of age".²⁰ As such, for 9–11-year-old children who have physically matured earlier than average, the RDIs for 12–18-year-olds may be more appropriate.

It is well known that severe calcium deficiency during infancy can exacerbate vitamin D deficiency and so lead to rickets. It is assumed that calcium provided by breast milk is adequate, which informs recommended intakes for infants. Puberty represents the next most vulnerable stage related to inadequate calcium intake, because about 40% of peak bone mass is acquired during this period.²¹ So, it is particularly concerning that a multinational study of calcium intakes, as a proportion of country-specific requirements, reported levels of 60% and 50% of adequate dietary calcium intake for adolescent boys and girls, respectively.²²

During early puberty, fracture incidence is high, in part because peak height velocity occurs before peak bone

mineral content (BMC) is accrued.²³ Increasing fracture incidence in recent decades has been attributed to decreased milk consumption, decreased physical activity and increased body fat. When an obese child falls, greater force will be exerted on the outstretched radius. In this situation, increased body weight is transmitted through the limb, resulting in force which may exceed the strength of the bone and so lead to fracture.

The evidence reviewed in *Building healthy bones throughout life* does not support the use of calcium supplements in healthy children (with the possible exception of those with very low calcium intakes). However, children with medical conditions that affect bone metabolism may require supplementation.

Vitamin D needs in pregnancy and childhood

Based on available evidence, the recommended blood level of 25-hydroxyvitamin D (25[OH]D) for infants, children and adolescents for optimal bone health is >50 nmol/L year round. The RDI for vitamin D in children and adolescents is 600 IU (15 µg) daily, assuming minimal sun exposure.

Vitamin D and calcium homeostasis are altered during pregnancy to allow calcium transfer to the fetus. No studies have been done to determine whether optimal 25(OH)D levels in pregnant women differ from those for non-pregnant women.²⁴ The effect of vitamin D on maternal bone health during pregnancy is also poorly documented. However, emerging evidence reviewed suggests that vitamin D may be protective for pre-eclampsia, gestational diabetes, bacterial vaginosis, and complications of pregnancy. Recent studies report low levels of vitamin D, defined as <50 nmol/L, in pregnant women from Sydney (48%),²⁵ Campbelltown, NSW (26%),²⁶ Canberra (35%)²⁶ and rural Victoria (26%).²⁷ The best study conducted to date on vitamin D supplementation during pregnancy showed doses of 4000 IU (100 µg) daily increased serum 25(OH)D to >80 nmol/L in all women and their neonates without safety concerns.²⁸ Accordingly, it is reasonable to measure vitamin D status in all pregnant women and use supplements as appropriate to achieve maternal levels >50 nmol/L.

There is currently limited evidence on the effect of vitamin D on maternal bone health during lactation and after weaning. As such, the target level of >50–60 nmol/L for healthy adults is deemed appropriate for breastfeeding mothers, and maternal vitamin D supplementation is not supported as a single strategy.

Rickets is defined as a generalised disruption of skeletal mineralisation (osteomalacia) in combination with abnormal growth plate mineralisation and development during periods of linear growth. While there is not an absolute level of 25(OH)D that is associated with rickets, most cases are attributable to low vitamin D. A common theme is evident among case series of children with rickets; most of those affected have dark skin and prolonged breastfeeding. A considerable number of studies of varying quality on the subject of healing of rickets are reviewed in *Building healthy bones throughout life*. A teaspoon of cod liver oil contains 400 IU (10 µg) of vitamin D, which has been shown to prevent rickets.²⁹

In children and adolescents with low levels of vitamin D, supplementation may be required. A position paper will provide guidance on appropriate dosing.³⁰

Exercise needs for children and adolescents

Childhood and adolescence may represent the optimal window of opportunity in which exercise can improve bone strength and protect against osteoporosis and associated fragility fractures in old age, assuming the gains achieved are

maintained in later life. Growing bone has a greater capacity to adapt to weight-bearing exercise than mature bone.³¹

Children who participate in moderate- to high-impact weight-bearing physical activities experience greater gains in BMC and BMD than less-active peers. A systematic review of trials reported exercise-induced gains in BMC and BMD over a 6-month period, ranging from 0.9% to 4.9% in prepubertal children and from 1.1% to 5.5% in early pubertal children, compared with matched controls.³² It would appear that the greatest skeletal benefits from exercise occur during the prepubertal years. The most significant responses to exercise interventions are observed at the sites subjected to the highest loads and frequencies. Jumping exercises seem to be associated with the largest gains.^{33,34} Recommendations on the requisite duration and frequency of exercise sessions are broad: 10–45 minute bouts occurring 3–7 days per week.

A key question is whether osteogenic gains during childhood translate to higher peak bone mass in adulthood. A recent Australian study suggests that fitness as a child is predictive of peak bone mass at age 30 years, regardless of the adult's current fitness level.³⁵

Building healthy bones in healthy adults

The primary objective in healthy adults is to prevent premature bone loss, which would predispose the individual to increased fracture risk in later life. In addition, improvement or maintenance of muscle mass, strength and functional capacity are important for balance and gait.

Calcium needs in healthy adults

The NHMRC RDIs for calcium for adults by age and sex are:²⁰

- 19–50 years: women, 1000 mg/day; men, 1000 mg/day;
- 51–70 years: women, 1300 mg/day; men, 1000 mg/day;
- >70 years: women, 1300 mg/day; men, 1300 mg/day.

The last Australian National Nutrition Survey reported that <75% of males and <50% of females had a calcium intake that exceeded the RDI.³⁶ Between 50% and 66% of calcium intake was provided by milk products. An adequate calcium intake achieved through diet is considered the best choice for people who can include a sufficient intake of dairy foods. In order to achieve a daily intake of 1000–1300 mg, at least three servings of dairy products are recommended.

There is a paucity of evidence regarding the role of calcium intake in maintaining bone mass or preventing fractures in young and middle-aged adults. The incidence of fragility fractures in this age group is low, and a large proportion of incident fractures are a result of high trauma.³⁷ As such, studies to determine associations between calcium intake and fracture incidence in healthy adults would require a very large number of subjects and are therefore unlikely to be conducted.

Calcium supplementation has been the subject of considerable debate and controversy over the past few years. Evidence of the role of calcium supplementation in the prevention of osteoporosis in perimenopausal women is equivocal.^{38,39} A series of meta-analyses has sought to evaluate a potential association between calcium supplementation and increased risk of ischaemic heart disease.^{40–43} These analyses found the incidence of myocardial infarction (MI) among postmenopausal women, as reported by the patient or her family, was significantly increased among women taking the calcium supplements. However, findings from other investigators are in stark contrast to those of the meta-analyses.^{44,45}

Putting this conflicting evidence into perspective, in order to reduce or prevent bone loss during adulthood, it

continues to appear vital to maintain an adequate intake of calcium. As such, Osteoporosis Australia continues to recommend that healthy adults achieve a daily calcium intake of 1000–1300 mg, dependent on age and sex. Ideally, this should be obtained from calcium-rich foods in the diet; however, when dietary intake is not sufficient, supplementation may be required at doses of 500–600 mg/day, particularly among people with low bone density.

Vitamin D needs in healthy adults

For the purposes of the following discussion, the age range for healthy adults is 20 to 65 years. As a primary source of vitamin D is appropriate exposure to sunshine, one of the recommendations of *Building healthy bones throughout life* provides specific guidance on appropriate duration and timing for sun exposure (see Recommendation 3 for all stages of life, below).

In 2011, a US Institute of Medicine report on dietary reference intakes for calcium and vitamin D considered the relationship between baseline or attained 25(OH)D status and changes in BMD for healthy adults;⁴⁶ five out of six studies considered found no association or did not report such findings. Regarding the effect of vitamin D supplementation on BMD, studies of daily doses of 800 IU (20 µg) of vitamin D (or lower equivalent doses of vitamin D₃ or D₂) reported equivocal findings. However, this dose is now considered suboptimal with respect to bone health, with doses of >2000 IU (50 µg) per day, viewed as the level at which beneficial effects on BMD will result. Because most study patients also received calcium supplementation, the Institute of Medicine concluded that both supplements were required for all age groups to achieve gains in BMD.

Data are sparse on the relationship between baseline 25(OH)D status and subsequent risk of fracture. By contrast, a considerable number of randomised controlled trials have evaluated the effect of vitamin D, with and without calcium, on fracture rates.⁴⁷ However, only two of these studies were conducted in subjects in the age range for healthy adults, and neither showed a reduction in fracture incidence as a result of taking vitamin D.^{48,49}

Exercise needs for healthy adults

Meta-analyses of the impact of exercise programs on BMD in premenopausal women report positive effects on bone density in the spine.^{50–55} An increase in lumbar spine BMD of about 1% per year has been reported for aerobic, high-impact and resistance training compared with sedentary controls.⁵⁰ Increases in femoral neck BMD have been reported for programs that combine weight-bearing aerobic and strength training⁵³ and high-impact aerobic exercise (eg, jumping or stepping).⁵⁶ One meta-analysis also reported significant increases in lean mass, muscle strength and a reduction in body fat,⁵² which may also attenuate future fracture risk.

The broadest range of benefits, both skeletal and otherwise, can be achieved by resistance training as the primary exercise modality. Moderate- to high-intensity progressive resistance training and/or high-impact training is recommended as the primary intensity of planned exercise in this group, because the physiological response is proportional to the magnitude and rate of strain imposed.⁵⁷ Jumping exercises that involve a jump of just 8 cm off the ground generate ground reaction forces of 3–4 times body weight and are therefore high impact. From a practical perspective, such exercises would be feasible for non-athletic women and can be completed in 2 minutes per day.

Building healthy bones in older adults and individuals with osteopenia and osteoporosis

The primary objective in older adults is to prevent and treat osteoporosis in order to minimise the risk of suffering fragility fractures. As fragility fractures usually result from a fall, assessment for falls risk, where appropriate, is a central component of fracture reduction strategies.

Calcium needs in older adults and individuals with osteopenia and osteoporosis

The NHMRC RDIs for calcium for older adults by age and sex are:²⁰

- 51–70 years: women, 1300 mg/day; men, 1000 mg/day;
- > 70 years: women, 1300 mg/day; men, 1300 mg/day.

The median dietary intake in the last Australian National Nutrition Survey was 827 mg/day for men aged > 65 years and 619 mg/day for women aged > 65 years.³⁶ Accordingly, older Australian men are almost achieving the EAR of 840 mg/day advocated by the NHMRC, while older women are significantly below their recommended EAR of 840–1100 mg/day.²⁰ To achieve a daily intake of 1000 mg–1300 mg of calcium, three servings of dairy products are recommended, with at least one of those being calcium-fortified. Provision of an annual estimate of average daily calcium intake to the individual and their doctor has been shown to improve calcium intake in the long term.⁵⁸ Given the proportion of women who have a low dietary intake of calcium, the findings of a survey published in 2000 are noteworthy: less than 7% of women took calcium supplements.⁵⁹

Skeletal calcium serves as a reserve to maintain the concentration of ionised calcium in the extracellular fluid. The parathyroid hormone–vitamin D system maintains plasma calcium at the expense of the skeleton by preserving levels of ionised calcium in the extracellular fluid through increased bone resorption. Accordingly, individuals with a low calcium intake, and/or those with reduced calcium absorption related to vitamin D deficiency, may develop osteopenia or osteoporosis.

The primary objective in older people and those with osteopenia and osteoporosis is to prevent them from suffering fragility fractures. In this regard, evidence from randomised controlled trials^{60–62} — which had fracture as a primary outcome — and meta-analysis⁶³ underscores the importance of ensuring adequate calcium intake in these populations. That being said, considerable heterogeneity in dose, baseline nutrient status, coadministration of vitamin D and poor adherence have contributed to inconsistent results. The role of calcium supplementation in the frail elderly, particularly female nursing home residents, is well established.⁶⁴ The same meta-analysis concluded that supplementation with calcium and vitamin D would reduce the relative risk of fracture in adults aged ≥ 50 years by 12%, and that doses of 1200 mg/day calcium and 800 IU (20 μ g)/day vitamin D were optimal. While a range of side effects associated with calcium supplementation may impact on adherence, a lack of motivation is the most commonly cited reason for non-adherence.⁶⁵

As discussed previously in the section on calcium needs in healthy adults, the focus of debate surrounding calcium supplementation has shifted from public health concerns related to poor adherence to a re-evaluation of the risk–benefit ratio. The most recently published reanalysis of the Women’s Health Initiative study and meta-analysis concludes that calcium supplements, taken with or without vitamin D, modestly increase the risk of cardiovascular events, especially MI.^{40,66} Given that the observed fracture reduction efficacy of calcium supplementation is modest,

the authors of these publications call for a reassessment of the role of calcium supplements in the management of osteoporosis. Other investigators take a different view,⁶⁷ highlighting the need for ongoing evaluation and discourse on this subject. It should be stated that the debate surrounding calcium supplementation does not extend to dietary calcium intake.

On the subject of calcium supplementation, *Building healthy bones throughout life* reaches the following conclusion:

As none of the trials reanalysed were primarily designed to investigate cardiovascular outcomes,⁶⁸ on balance, current evidence does demonstrate a small increase in risk of MI with calcium supplements. Using Women’s Health Initiative data, based on the worst-case scenario, treatment of 1000 people with calcium or calcium and vitamin D for 5 years would cause an additional six MIs or strokes and prevent three fractures.⁶⁹ However, mortality is not increased and, in fact, the combination of vitamin D with calcium supplements has been found to reduce mortality in the elderly by 7%.⁷⁰

A cohort study also shows that self-reported calcium supplement use was associated with a 9% reduction in mortality in older women.⁷¹ If calcium and vitamin D are taken more than 80% of the time, the prevalence of fractures has been found to decrease by 24% in older men and women.⁶⁴

Calcium or calcium–vitamin D supplements may be beneficial for general health as well as reducing fracture risk in people who may not be getting enough calcium through their diet.⁷⁰ Nevertheless, dietary calcium is the preferred source of calcium, and calcium supplements should be limited to 500–600 mg per day.

Vitamin D needs in older adults and individuals with osteopenia and osteoporosis

Based on available evidence, the recommended blood level of 25(OH)D for older adults and individuals being treated with anti-osteoporotic drugs is >50 nmol/L at the end of winter or >60 nmol/L in summer. Older Australians, particularly those living in aged care facilities, are at high risk of vitamin D deficiency.^{72–74} While a diminished capacity to synthesise vitamin D in the skin of older individuals may contribute to the prevalence of vitamin D deficiency, limited sun exposure due to frailty, reduced mobility or preference presents a greater problem.⁷⁵ The average dietary intake of vitamin D is estimated to be 104–120 IU (2.6–3.0 μ g)/day for men and 80–88 IU (2.0–2.2 μ g)/day for women.⁷⁶ As the adequate intake of vitamin D is ≥ 600 IU (10 μ g)/day for older people, the impact of reduced exposure to sunshine is self-evident.

The impact of vitamin D supplementation on falls and fracture incidence has been evaluated in meta-analyses. Falls incidence was reduced by 19% in older individuals with vitamin D deficiency when treated with daily doses >700–800 IU (17.5–20 μ g) and when serum 25(OH)D levels exceeded 60 nmol/L.⁷⁷ Vitamin D treatment alone has not been shown to reduce fracture risk. However, in combination with calcium, a daily dose of at least 800 IU (20 μ g) was shown to have a modest benefit on fracture rates in people aged >50 years.⁶⁴ With respect to individuals who have already suffered fragility fractures, there is no evidence to support treatment with vitamin D, alone or in combination with calcium.^{47,60} Such individuals should be treated with anti-osteoporotic drugs in accordance with national guidelines.¹³ A serum level of ≥ 50 nmol/L should be the target for individuals taking antiresorptive drugs to optimise skeletal response, which will

require daily doses of 800–2000 IU (20–50 µg) of vitamin D for most patients.⁷⁸

Exercise needs for older adults and individuals with osteopenia and osteoporosis

The role of exercise with respect to fragility fracture prevention in older adults is to attenuate bone loss in perimenopausal women, prevent sarcopenia after the menopause and address risk factors for falls and frailty in the very old.

Recent meta-analyses suggest that the beneficial effect of exercise on bone in older adults is both modality- and intensity-dependent.^{55,79,80} As a general rule, the older the individual, the more favourable resistance training appears to be. There is a relative paucity of evidence on the impact of exercise programs on bone health in older adults. However, a study comparing supervised high-intensity resistance training with low-intensity home-based physical therapy reported greater BMD gains for the high-intensity group.⁸¹ Emerging evidence suggests that multimodal exercise, which includes weight-bearing, high-impact and high-intensity resistance training, significantly reduces fracture risk.⁷⁹

Individuals with osteopenia, osteoporosis and those who have suffered fragility fractures should avoid forward flexion of the spine. This would include activities such as lawn bowling and doing sit-ups with straight legs, on account of the risk of anterior compression fractures of thoracic vertebrae. Among individuals who have suffered fragility fractures, exercise programs have been demonstrated to assist in recovery of function,⁸² prevent recurrent injurious falls⁸³ and improve quality of life.⁸⁴

Recommendations

The mandate of the 2011 Osteoporosis Australia Summit was to develop clear evidence-informed recommendations concerning calcium, vitamin D and exercise requirements for building healthy bones in children, healthy adults, and older adults and individuals with osteopenia and osteoporosis. The bone mass changes throughout the life cycle depicted in Box 1 illustrate how the primary objectives relating to bone health alter at different stages. The recommendations that follow describe calcium, vitamin D and exercise needs relevant to all stages of life, and also highlight specific needs during childhood, midlife and old age.

Recommendations for all stages of life

Calcium

1. Eat sufficient and nutritious foods for growth and development.
 - a. Daily dietary calcium intakes should be consistent with the Australian and New Zealand guidelines for an adequate calcium intake.²⁰
 - b. It is agreed that a diet low in calcium increases the risk of bone loss and fracture. The Australian and New Zealand guidelines for an adequate calcium intake are described above.
 - c. Calcium needs are increased during the adolescent growth spurt.
 - d. Practically, people should aim to include 3–5 serves of calcium-rich foods daily (eg, dairy or calcium-fortified foods), as the preferred means of achieving an adequate calcium intake. Box 2 provides the calcium content of key foods.
 - e. Individuals who dislike or are intolerant of dairy products and wish to achieve their required calcium intake from diet will need to have more

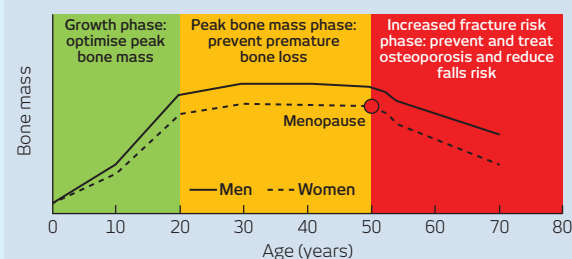
serve of other high-calcium-containing foods (eg, specific vegetables, fish, nuts) or calcium-fortified foods (eg, soy milk).

- f. For people with inadequate dietary calcium intake (below the EAR/RDI), calcium supplements are recommended and are as effective as dietary sources. Under these circumstances, calcium supplementation with 500–600 mg per day is indicated.
2. Achieve and maintain a healthy body weight to maintain muscle mass, particularly guarding against underweight and overweight.
 - a. In population studies, fracture risk is increased in females with low BMI and body fat, especially if body weight is sufficiently low to impair sex hormone production.
 - b. Population studies also show that obesity is not protective against fractures in some individuals.^{85,86}
 - c. Sarcopenia is associated with low BMD and an increased risk of fracture.^{87–90}

Vitamin D

3. Ensure adequate vitamin D levels.
 - a. Sun exposure is the primary source of vitamin D. Encourage regular and safe sunlight exposure (avoiding burning), in accordance with current Australian and New Zealand Bone and Mineral Society, Endocrine Society of Australia and Osteoporosis Australia recommendations.⁹¹ However, there is a need for more research in this area. Box 3 provides guidance on recommended sun exposure from the vitamin D position statement supported by the Australian and New Zealand Bone and Mineral Society, the Endocrine Society of Australia and Osteoporosis Australia.⁹¹
 - b. Maintaining adequate vitamin D is critical for calcium absorption and is also important for optimal bone health and muscle function.
 - c. There is general agreement that serum levels of 25(OH)D in the general population should be above 50 nmol/L at the end of winter or in early spring for optimal bone health.
 - d. Most adults will not receive more than 5%–10% of their vitamin D requirements from dietary sources. In healthy adults, the main contributor to circulating vitamin D levels is vitamin D produced in the skin in response to sunlight exposure.
 - e. Current evidence does not support a case for food fortification with vitamin D. More evidence on whether there is widespread vitamin D deficiency is required before such a case can be supported.

1 Bone mass changes throughout the life cycle



2 Calcium content of key foods

Foods	Calcium content (mg per standard serve)
Milk, cheese and yoghurt	300–400
Tinned salmon and sardines	220–400
Calcium-set tofu	150
Nuts and tahini	65–110
Selected green vegetables	18–43

Source: adapted from the Food Standards Australia and New Zealand database, with cross reference to FoodWorks 7 and CalorieKing Australia. ◆

- f. If sun exposure is limited or there are other risk factors for vitamin D deficiency (dark skin, clothing covering the skin, conditions affecting vitamin D metabolism, breastfed babies with other risk factors), it is important to measure the serum 25(OH)D level and take vitamin D supplements in doses that will maintain serum 25(OH)D levels over 50 nmol/L year round.
- g. For people who do not get adequate exposure to sunlight, vitamin D supplements provide a means of increasing vitamin D intake. To treat moderate to severe deficiency, it would be reasonable to use 3000–5000 IU (75–125 µg) of vitamin D supplements per day for at least 6–12 weeks, with most patients requiring ongoing treatment at a maintenance dose of around 1000–2000 IU (25–50 µg) per day. Higher doses of 2000–4000 IU (50–100 µg) per day may be required in some individuals (eg, if obese).

Exercise

- 4. Undertake regular weight-bearing physical activity, muscle-strengthening exercises and challenging balance/mobility activities in a safe environment and promote a healthy lifestyle.
 - a. Encourage regular participation in a variety of weight-bearing activities, including dynamic

impact-loading sports (eg, basketball, netball, hockey, football, soccer), school-based physical education classes and regular outside play, for at least 30 minutes 3–5 days per week.

- b. For healthy individuals (without osteoporosis) with few risk factors for fracture, the key focus of exercise and physical activity is to improve or maintain bone density, muscle mass, strength and functional capacity (balance, gait). A combination of weight-bearing and resistance training is recommended.
 - c. Some examples of the impact of particular exercises on bone health are shown in Box 4.
5. For individuals with osteoporosis and/or at increased risk of falling, challenging balance and mobility exercises are recommended.
 6. Exercise offers greater skeletal benefits when undertaken with a diet containing an adequate intake of calcium (equivalent to the EAR/RDI).
 7. Avoid prolonged periods of sedentary behaviours (sitting), due to detrimental effects on bone and cardiovascular health.

Other

8. Encourage health promotion models to reduce uptake of smoking, dieting behaviours and alcohol use.
 - a. If alcohol is consumed, it should be consumed in moderation — up to one standard drink per day for women and two standard drinks per day for men.
 - b. Excessive alcohol intake is a cause of fracture, because of an increased propensity to fall.
 - c. Excessive alcohol also impairs bone formation.
 - d. Do not smoke. Smoking is associated with a reduction in bone structure and strength.
9. Maintain normal sex hormone levels for the stage of life, and correct levels as appropriate in premenopausal women and men.
10. Test for bone health.
 - a. Population-based vitamin D testing using a blood sample is not recommended.
 - b. Vitamin D testing is not recommended in otherwise healthy individuals who do not have risk factors or disorders predisposing to osteoporosis and minimal trauma fracture.
 - c. If sunlight exposure is very low or there are other risk factors for vitamin D deficiency (dark skin, absence of skin exposure), testing may be recommended. If vitamin D testing is recommended, it should be done at the end of winter or in early spring.
 - d. Consider bone density testing, using dual energy x-ray absorptiometry, in the presence of risk factors or at age ≥ 70 years in the absence of risk factors.

3 Recommended sun exposure requirements to meet adequate vitamin D levels⁹¹

	Summer	Winter
For people with moderately fair skin		
How long?	6–7 minutes, most days	7–40 minutes (depending on latitude), most days
Body area exposed?	Arms exposed	As much bare skin exposed as practical
When?	At 10 am or 2 pm (standard time), 11 am or 3 pm (daylight saving time); avoid peak UV times	Midday
For people with darker skin*		
How long?	18–42 minutes most days	21 minutes to 4 hours (depending on latitude)
Body area exposed?	Arms exposed	As much bare skin exposed as practical
When?	At 10 am or 2 pm (standard time), 11 am or 3 pm (daylight saving time); avoid peak UV times	Midday

UV = ultraviolet. *People with dark skin are likely to need sun exposure three to six times longer. ◆

Recommendations for building healthy bones in children

In addition to the above general recommendations, these recommendations are designed to provide advice to parents and carers relating to steps they can take to promote healthy bone growth in children. They are also intended to provide public health recommendations during pregnancy and lactation, childhood, and the teenage years.

Peak bone mass is acquired during late adolescence and early adulthood and sets the stage for vulnerability to fracture and other bone disorders later in life. The 2 years around puberty is a particularly important period to maintain adequate calcium and engage in weight-bearing exercise, as

4 The impact of selected exercises on bone health

Highly osteogenic	Moderately osteogenic	Low osteogenic*	Non-osteogenic*
Basketball/netball	Running/jogging	Leisure walking	Swimming
Impact aerobics	Brisk or hill walking	Lawn bowls	Cycling
Dancing/gymnastics	Resistance training	Yoga/Pilates/tai chi	
Tennis	Stair climbing		
Jump rope			

* While certain exercises may have low or no osteogenic benefits, this should not be construed to imply that these exercises do not offer a wide range of other health benefits. ◆

about 40% of adult peak bone mass is acquired during this period.²⁰

1. Ensure adequate calcium intake.
 - a. Encourage and support breastfeeding. Breast milk is an important source of calcium. Infants should be exclusively breastfed to 6 months of age and continue to be breastfed, with complementary foods, until 12 months.
 - b. Reduced-fat milk products are not suitable for children under 2 years of age.
2. Ensure adequate vitamin D.
 - a. Promote adequate maternal vitamin D status during pregnancy.
 - b. Breastfed babies from women at risk of vitamin D deficiency require supplementation.
 - c. Children with chronic illness or disability warrant special consideration of their vitamin D status and bone health.
3. Engage in regular weight-bearing activity and promote a healthy lifestyle.
 - a. Encourage schools to incorporate a diverse and enjoyable battery of weight-bearing activities and sports into their school physical education programs. This could include participation in short periods (5–10 minutes) of daily, targeted, multidirectional, moderate- to high-impact activities such as jumping, skipping and hopping.

Building healthy bones in healthy adults

These recommendations are designed to augment the general recommendations and provide specific advice to healthy adult individuals relating to steps they can take themselves to reduce the risk of fracture in the future. They also include public health recommendations for the prevention of fracture in adults who have achieved peak bone mass and are at low risk of fracture. Because fracture risk increases with age, these recommendations are particularly important for individuals who wish to maintain their bone strength into old age, and especially for postmenopausal women and older individuals to maintain their bone strength.

The needs of adults with specific disorders affecting the skeleton (eg, osteoporosis, coeliac disease) are not addressed in these recommendations; these individuals should seek specific medical advice appropriate to the condition.

1. Ensure adequate vitamin D levels (see Recommendation 3 for all stages of life).
2. Be habitually physically active and undertake regular weight-bearing and/or muscle-strengthening exercises.
 - a. Encourage regular participation in moderate-impact weight-bearing physical activity, high-impact training (eg, 50–100 jumps) or related impact-loading sports for at least 30 minutes 3–5 days per week.

- b. Include muscle-strengthening exercises on at least 2 days per week. For maximum benefits, the program should be high intensity (60%–80% of peak capacity), become progressively more challenging over time, and target the major muscles around the hip and spine.
- c. Where possible, encourage participation in a multimodal exercise regimen (including weight-bearing/high-impact/high-intensity resistance exercise) at least three times per week.

Building healthy bones in older adults and individuals with osteopenia and osteoporosis

These recommendations are designed to supplement the general recommendations and provide specific advice to individuals relating to steps they can take themselves to reduce fracture risk, and to provide them with information on how best to access appropriate health advice. They are public health recommendations for the prevention of fracture in adults >50 years of age who are at higher risk of fracture, defined as having a 5-year absolute risk of fracture over 5%.

Adults with specific disorders (such as coeliac disease or conditions for which they take oral corticosteroids) that may be responsible for their low bone density should also seek specific medical advice appropriate to the condition.

Adults with a 5-year absolute risk of fracture over 10% should also seek specific advice on the management of osteoporosis, if present, which is well covered in the Royal Australian College of General Practitioners' *Clinical guideline for the prevention and treatment of osteoporosis in postmenopausal women and older men*.¹³

1. Dietary calcium intakes should be consistent with the Australian and New Zealand guidelines for an adequate calcium intake.²⁰
 - a. Calcium intake by diet is strongly recommended, but calcium supplements at doses of 500–600 mg per day may be required in some individuals when calcium from dietary sources is not possible.
 - b. Current concerns over the potential for an increased risk of MI with calcium supplements are still being debated but should not alter acceptance of the recommendation. Mortality has not been increased in any study of calcium supplements.
2. Vitamin D plays an important role in bone health.
 - a. In addition to the general recommendations made in Recommendation 10 for testing bone health at all stages of life, vitamin D level should be established by measuring vitamin D levels in the blood in the following situations:
 - osteoporosis when diagnosed by bone density testing;
 - after falling;
 - following a minimal trauma fracture.

- b. If 25(OH)D levels are below the desirable level, the following doses are recommended:
 - supplementation with vitamin D capsules or tablets is recommended in doses of 1000–2000 IU (25–50 µg) per day;
 - higher dose intermittent therapy, eg, 50 000 IU (1250 µg) per month, is an alternative, although more data on the safety of monthly dosing are required.
- c. The desired outcome of vitamin D supplementation is:
 - a reduced risk of fractures if serum 25(OH)D levels are above 75 nmol/L;
 - a reduced risk of falls if serum concentrations are above 60 nmol/L;
 - individuals with serum 25(OH)D levels above 50 nmol/L at the end of winter or early in spring are likely to have levels of 60–75 nmol/L for much of the remainder of the year.
3. For older adults, the elderly and those with or at risk of osteoporosis, falls and fracture, the key focus of exercise should be to not just slow bone loss, but to increase or maintain muscle mass and muscle strength, and to improve muscle function, gait and mobility to reduce the risk of falls and fractures.
 - a. Encourage participation in a multimodal and supervised exercise program that includes weight-bearing activities, progressive resistance training and high challenging balance and functional activities at least three times per week.
 - b. It is important that muscle groups connected to bones of relevance to osteoporotic fracture be emphasised in such programs (eg, spinal extensor muscles, hip abductors, hip extensors, knee extensors/flexors) and those related to gait and balance (ankle plantar flexors and dorsiflexors, inverters and everters, hip abductors).
 - c. Regular leisure-time walking should be encouraged for its benefits on weight control and cardiovascular health. For skeletal health benefits, it is recommended that individuals progress to brisk or hill walking and then to other forms of moderate-impact weight-bearing exercises.
 - d. Elderly people with osteoporosis and a history of fracture should avoid exercises or activities that involve forward flexion of the spine, particularly while carrying weights.
 - e. Maintain safe environments to avoid falls and encourage falls education. Elderly individuals should consider and address risk factors for falls (vision problems, use of sedatives, postural hypotension, environmental hazards).

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