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Nutrient Reference Values for Australia and New Zealand
Including Recommended Dietary Intakes

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CALCIUM

BACKGROUND

Calcium is required for the normal development and maintenance of the skeleton as well as for the proper functioning of neuromuscular and cardiac function. It is stored in the teeth and bones where it provides structure and strength. Low intakes of calcium have been associated with a condition of low bone density called osteoporosis which is quite common in western cultures and which often results in bone fracture. It is one of the major causes of morbidity amongst older Australians and New Zealanders, particularly postmenopausal women. Calcium intake throughout life is a major factor affecting the incidence of osteoporosis, however other factors, notably adequate vitamin D status and exercise, also play a role.

Bone mass increases by about sevenfold from birth to puberty and a further threefold during adolescence (Peacock 1991) and then remains stable until about age 50 in men and until the menopause in women. During the adolescent growth spurt, the required calcium retention is two to three times higher than that required for the development of peak bone mass which occurs at the same time as maximum height (Nordin et al 1979).

For approximately 5–10 years both during and after the climacteric and menopause (Heaney 1986), women lose bone more rapidly than men (2%–3% per year). Thereafter, the age-related loss in both sexes is about 0.5 to 1.0% per annum. All of the body's calcium reserve is stored in the skeleton. The size of the reserve is directly affected by the body's external calcium balance which depends on the relation between calcium intake and absorption on the one hand and losses of calcium through the skin, kidney and bowel on the other.

Until recently, the amount of dietary calcium needed to replace losses through sweat had not been included in estimates of calcium requirements. This omission accounts to a large extent for an apparent increase in calcium intake recommendations seen in the recent revisions of the FAO:WHO (2001) and US:Canadian (FNB:IOM 1997) recommendations and in the current revision of the Australian/New Zealand recommendations.

Calcium balance deteriorates at menopause when there is a decline in intestinal calcium absorption and/or an increase in urinary calcium excretion. In post menopausal women, there is evidence that a high calcium intake will slow the rate of bone loss and may reduce the risk of fracture (Cumming & Nevitt 1997, Dawson-Hughes et al 1990, Elders et al 1994, Nordin 1997, Prince et al 1995, Reid et al 1993, 1995) but it has been suggested that the improvement may attenuate over time (Mackerras & Lumley 1997).

A systematic review was also undertaken by Cumming & Nevitt (1997) of 14 studies of calcium supplements (including 4 RCTs), 18 studies of dietary calcium and hip fracture (no RCTs), and 5 studies of dietary calcium and other fracture sites (no RCTs). The 4 RCTs of calcium supplements (mean calcium dose 1,050 mg) found relative risk (RR) reductions of between 25% and 70%. Cochrane reviews by Shea et al (2003, 2004) also concluded that calcium supplementation had a small positive effect on bone density and a trend towards reduction in vertebral fractures but concluded that it was unclear if calcium reduces the incidence of non-vertebral fractures. However, one recent large intervention trial in 5,292 previously ambulatory elderly people who had already experienced a fracture showed no effect on the occurrence of further fractures of calcium and/or vitamin D supplements at levels of 1,000 mg calcium or 20 µg daily oral vitamin D3 alone or in combination (Grant et al 2005).

Calcium is found predominantly in milk and milk-based foods, with smaller amounts in bony fish, legumes and certain nuts, fortified soy beverages and breakfast cereals. Consumption of vegetarian diets may influence calcium needs because of their relatively high oxalate and phytate content, however, on balance, lacto-ovo-vegetarians appear to have similar calcium intakes to omnivores (Marsh et al 1980, Pedersen et al 1991, Reed et al 1994) and similar urinary excretion (Lloyd et al 1991, Tesar et al 1992).

Vegans have a lower calcium intake than vegetarians and omnivores (Larsson & Johansson 2002, New 2004), however one study by Kohlenberg-Mueller & Raschka (2003) has shown that both lactovegetarians and vegans can attain calcium balance. Intakes of calcium in adults in Australia and New Zealand average about 850 mg of which about 40% comes from non-milk sources.

For natural food sources of calcium, content is of equal or greater importance than bioavailability. The efficiency of calcium absorption varies across foods as calcium may be poorly absorbed from foods rich in oxalic acid (eg spinach, rhubarb, beans) or phytic acid (seeds, nuts, grains, certain raw beans and soy isolates). Absorption from soy milk can be, but is not always, as high as that from milk. Compared to milk, calcium absorption from dried beans is about 50% and from spinach, 10%.

Bioavailability from non-food sources (eg supplements) depends on the dosage and whether they are taken with a meal. In standardised studies of 250 mg calcium supplements given with a breakfast meal, absorption from supplements gave fractional absorption rates of 25–35% compared to a rate for calcium from milk of 29% (Heaney et al 1989, 1990, Miller et al 1988, Smith et al 1987). Efficiency of absorption of calcium from supplements is greatest at doses of 500 mg or less (Heaney et al 1975, 1988), but once the active transport mechanism is saturated, only 5–10% of additional calcium is absorbed.

Sodium intake can also affect calcium requirements as sodium and calcium excretion are linked in the kidney tubules (Nordin & Polley 1987, Matkovic et al 1995, O'Brien et al 1996, Devine et al 1995) – 2,300 mg of sodium takes out about 40 mg of calcium. The amount of protein in the diet can also affect calcium need. High intakes of protein increase urinary calcium excretion (Linkswiler et al 1981, Margen et al 1974) – each gram of protein takes out 1 mg of calcium. In contrast, diets that are particularly low in protein have also been shown to be of concern in terms of bone health, possibly due to lowered calcium absorption (Cooper et al 1996, Geinoz et al 1993, Hannan et al 2000, Kerstetter et al 2003a,b). The effect of protein on calcium retention is unclear (Delmas 1992, Walker & Linkswiler 1972).

Indicators that have been used to assess calcium requirements include balance studies, factorial estimates of requirements or assessment of changes in bone mineral density and bone mineral content. In setting the Australian and New Zealand recommendations, a balance approach used for the earlier Australian /New Zealand RDIs and used by FAO:WHO in their 2001 revision of *Human Vitamin and Mineral Requirements* (FAO:WHO 2001) was adopted. Other approaches, such as the various methods used by the US:Canadian DRI review (FNB:IOM 1997) give widely varying and inconsistent results, making interpretation problematic.

For adults, the results of 210 balance studies on normal individuals quoted in the FAO:WHO report were used to calculate calcium requirements. The estimate was based on the intake at which excreted calcium equals net absorbed calcium, adding an allowance for insensible losses. In postmenopausal women, allowance was made for an additional loss of calcium in urine.

The calcium requirements for other age/gender/physiological groups, for whom there were few balance studies, were estimated from the amount of calcium that each group must absorb in order to meet obligatory calcium losses, together with a consideration of their desirable calcium retention and then calculation of the intake required to provide this necessary rate of calcium absorption. The only exception to this was for infants in whom the concentration of calcium in breast milk formed the basis of recommendations.

1 mmol calcium = 40 mg calcium

RECOMMENDATIONS BY LIFE STAGE AND GENDER

Infants	AI	Calcium
0–6 months	210 mg/day	
7–12 months	270 mg/day	

***Rationale*:** The AI for 0–6 months was set by multiplying together the average intake of breast milk (0.78 L/day) and the average concentration of calcium in breast milk (264 mg/L) from 10 studies reviewed by Atkinson et al (1995), and rounding. Formula-fed babies require additional intakes in the vicinity of 350 mg/day as calcium is less bioavailable in formula. The AI for infants 7–12 months was set by adding an estimate for calcium from breast milk at this age, to an estimate of intake from supplementary foods. A breast milk volume of 0.60 L/day was assumed at older ages (Dewey et al 1984). The concentration of calcium in breast milk at this age averages 210 mg/L (Atkinson et al 1995). This gives a contribution of 126 mg/day from breast milk that is added to 140 mg/day from complementary foods (Abrams et al 1997, Specker et al 1997) and rounded, giving an AI of 270 mg/day.

Children & adolescents	EAR	RDI	Calcium
All			
1–3 yr	360 mg/day	500 mg/day	
4–8 yr	520 mg/day	700 mg/day	
Boys			
9–11 yr	800 mg/day	1,000 mg/day	
12–13 yr	1,050 mg/day	1,300 mg/day	
14–18 yr	1,050 mg/day	1,300 mg/day	
Girls			
9–11 yr	800 mg/day	1,000 mg/day	
12–13 yr	1,050 mg/day	1,300 mg/day	
14–18 yr	1,050 mg/day	1,300 mg/day	

***Rationale*:** The EAR for children 1–8 years was set by modelling the components of calcium requirements, including a component for skeletal growth (FAO:WHO 2001). Requirements were estimated from data on accumulation of whole-body calcium, which was converted to a daily rate of calcium accretion. This, together with consideration of urinary calcium losses, dermal losses and daily skeletal increments, gives an estimate of daily net absorbed calcium needs. For children 1–8 years, this results in a figure of about 220 mg. EARs were set for this age band based on the estimated amounts needed – 440 mg/day on average – to provide this level of absorbed calcium, assuming absorption rates of 1 SD above those of adults. A lower figure of 360 mg/day was applied to the younger age band as their requirements will be less and 520 mg/day to the older group, on an approximate body weight basis. The RDI was set assuming a CV of 15% for the EAR (as variation in the needs of children and adolescents are likely to be greater than for adults) and rounding, giving an RDI of 500 mg/day for 1–3 year-olds and 700 mg/day for 4–8 year-olds.

From 9–11 years of age, calcium accretion rates are similar to those in younger children with EARs being 800 mg/day, assuming absorption at 1 SD above that for adults. There is a striking increase in the rate of skeletal calcium accretion from 12 to 18 years of age (FAO:WHO 2001). For this age group, net absorbed calcium needs to be 440 mg. Assuming high calcium absorption (+2 SDs above that for adults) this requires an EAR of 1,046 mg/day. Assuming a CV of 15% for the EAR, this gives an RDI of 1,300 mg in the older adolescents. For children aged 9–11 years who have physically matured much earlier than average, the recommendations for 12–18 year-olds may be more appropriate.

Adults	EAR	RDI	Calcium
Men			
19–30 yr	840 mg/day	1,000 mg/day	
31–50 yr	840 mg/day	1,000 mg/day	
51–70 yr	840 mg/day	1,000 mg/day	
>70 yr	1,100 mg/day	1,300 mg/day	
Women			
19–30 yr	840 mg/day	1,000 mg/day	
31–50 yr	840 mg/day	1,000 mg/day	
51–70 yr	1,100 mg/day	1,300 mg/day	
>70 yr	1,100 mg/day	1,300 mg/day	

***Rationale*:** The EAR for adults was set by calculating calcium requirement as the intake at which excreted calcium equals net absorbed calcium, based on the results of 210 balance studies on 81 subjects (FAO:WHO 2001). This occurs at an intake of 520 mg/day to which losses through sweat must be added. Insensible losses of calcium have been estimated at 60 mg/day (Charles et al 1983, Hasling et al 1990). Taking the low absorption that occurs at about 500 mg/day into account, an additional intake of 320 mg is required to cover these losses, increasing the EAR to 840mg. At menopause, an additional 30 mg is lost in urine (Nordin et al 1999) and absorption probably decreases (Heaney et al 1989, Nordin 1997) raising the EAR to 1,100 mg. This gives an RDI of 1,000 mg/day for men and premenopausal women, and 1,300 mg for postmenopausal women (EAR+2SD = RDI), assuming a CV of 10% for the EAR.

Little is known about calcium metabolism in the elderly, but absorption is known to decrease with age in both sexes (Ebeling et al 1994, Morris et al 1991, Need et al 1998). Data for increased need at menopause are strong but those for older men are not. As a precaution, an additional average requirement of 250 mg/day is recommended, translating to an additional 300 mg for the RDI.

Pregnancy	EAR	RDI	Calcium
14–18 yr	1,050 mg/day	1,300 mg/day	
19–30 yr	840 mg/day	1,000 mg/day	
31–50 yr	840 mg/day	1,000 mg/day	

***Rationale*:** The EAR and RDI for pregnancy were based on the needs of the mother plus any additional allowance for the fetus and products of conception. The fetus retains about 25–30 g, mostly in the third trimester of pregnancy, but there is evidence that pregnancy is associated with increased calcium absorption (Cross et al 1995a, Heaney & Skillman 1971, Kent et al 1991, Kumar et al 1979). Significant increases in maternal calcium accretion, bone turnover and intestinal absorption early in pregnancy before fetal bone mineralisation have also been shown (Heaney & Skillman 1971, Purdie et al 1988).

Dietary calcium intake does not appear to influence changes in maternal bone mass in pregnancy (Raman et al 1978) and there is no relationship between the number of previous pregnancies and bone mineral density (Alderman et al 1986, Koetting & Warlaw 1988, Kreiger et al 19832, Walker & Linkswiler 1972, Wasnich et al 1983) or fracture risk (Johansson et al 1993). Indeed, some studies show a positive correlation between number of children born and radial bone mineral density or total body calcium (Aloia et al 1983) as well as reduction in the risk of hip fracture (Hoffman et al 1993).

These findings support the concept that maternal skeleton is not used for fetal calcium needs. The work of Prentice (2003) also confirms no additional need for calcium in pregnancy. The available information thus does not support the need for additional dietary intake in pregnancy as maternal adaptive mechanisms including enhanced efficiency of absorption more than meet the additional needs in the last trimester. The implication is that normal calcium intake is sufficient to meet the calcium requirement in the pregnant state.

Lactation	EAR	RDI	Calcium
14–18 yr	**1,050 mg/day**	**1,300 mg/day**	
19–30 yr	**840 mg/day**	**1,000 mg/day**	
31–50 yr	**840 mg/day**	**1,000 mg/day**	

***Rationale*:** During pregnancy, 210 mg calcium/day on average is secreted in milk. The primary source of this calcium appears to be from increased maternal bone resorption (Affinato et al 1996, Dobnig et al 1995, Kent et al 1990) which is independent of calcium intake (Cross et al 1995b, Sowers et al 1995, Specker et al 1994). This bone loss is replaced after weaning. There is no evidence that the calcium intake of lactating women should be increased above that of non-lactating women.

UPPER LEVEL OF INTAKE - CALCIUM

Infants	
0–12 months	**Not possible to establish**
Children and adolescents	
1–3 yr	**2,500 mg/day**
4–8 yr	**2,500 mg/day**
9–13 yr	**2,500 mg/day**
14–18 yr	**2,500 mg/day**
Adults 19+ yr	
Men	**2,500 mg/day**
Women	**2,500 mg/day**
Pregnancy	
14–18 yr	**2,500 mg/day**
19–50 yr	**2,500 mg/day**
Lactation	
14–18 yr	**2,500 mg/day**
19–50 yr	**2,500 mg/day**

***Rationale*:** Because of the inverse relationship between fractional calcium absorption and calcium intake, an additional intake of 1,000 mg added to a typical western diet would only increase calcium in urine by about 60 mg. Urinary calcium rises slowly with intake and risk of developing kidney stones (nephrolithiasis) from calcium supplements is therefore negligible. Toxic effects of calcium have only been seen when calcium is given in high doses as the carbonate as an antacid. The result is hypercalcaemia with renal calcification and renal failure and is known as the milk alkali syndrome or MAS (Burnett et al 1949).

Using MAS as the critically defined endpoint, a LOAEL of about 5 g can be identified for adults from 16 studies involving 26 subjects (FNB:IOM 1997).

A UF of 2 takes into account the potential for increased risk of high calcium intake, given the relatively common occurrence of kidney stones in Australia and New Zealand, the fact that hypercalciuria in people with renal stones has been shown to occur at intakes as low as 1,700 mg /day in men and 870 mg in women (Burtis et al 1974) and concern that calcium will interfere with absorption of other minerals such as zinc and iron in vulnerable populations. The UL is therefore set conservatively at 2,500 mg/day.

As there is little evidence for other age and physiological groups, this figure is used for all age and gender groups and physiological states, particularly in relation to the need to prevent interference with zinc and iron absorption.

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