

The following is an extract from:

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

ENDORSED BY THE NHMRC ON 9 SEPTEMBER 2005

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ISBN Print 1864962372
ISBN Online 1864962437

The Nutrient Reference Values (NRVs) was a joint initiative of the Australian National Health and Medical Research Council (NHMRC) and the New Zealand Ministry of Health (MoH). The NHMRC would like to thank the New Zealand MoH for allowing the use of the NRV material in the development of this website.

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MAGNESIUM

BACKGROUND

Magnesium is a cofactor for more than 300 enzyme systems (Wacker & Parisi 1968) and is involved in both aerobic and anaerobic energy generation and in glycolysis, either directly as an enzyme activator or as part of the Mg-ATP complex. Magnesium is required for mitochondria to carry out oxidative phosphorylation. It plays a role in regulating potassium fluxes and in the metabolism of calcium (Al-Ghamdi et al 1994, Classen 1984, Waterlow 1992,). The human body contains about 760 mg of magnesium at birth and 25 g in adulthood (Forbes 1987, Schroeder et al 1969, Widdowson et al 1951). Just over half the body's magnesium is found in bone, where it forms a surface constituent of the hydroxyapatite mineral component, and a further third is found in muscles and soft tissues (Heaton 1976, Webster 1987). The intracellular concentration is about ten times that of the extracellular fluid.

Magnesium is widely distributed in the food supply in both plant and animal foods. Most green vegetables, legumes, peas, beans and nuts are rich in magnesium, as are some shellfish and spices. Most unrefined cereals are reasonable sources, but highly refined flours, tubers, fruits, oils and fats contribute little. Between 50% and 90% of magnesium in breast milk or infant formula is absorbed (Lonnerdal, 1995, 1997). In adults on conventional diets, the efficiency of absorption varies greatly with magnesium content (Seelig 1982, Spencer et al 1980) ranging from 25% on high magnesium diets in one study to 75% on low magnesium diets (Schwartz et al 1984). The homeostatic capacity of the body to adapt to a wide range of intakes is thus high (Abrams et al 1997, Sojka et al 1997).

Magnesium is absorbed in the duodenum and ileum by both active and passive processes (Greger et al 1981). High fibre intakes (40–50 g/day) lower magnesium absorption, probably because of the magnesium-binding action of the phytate phosphorus associated with the fibre (Kelsay et al 1979, McCance & Widdowson 1942a,b). There is no consistent evidence that moderate increases in calcium, iron or manganese affect magnesium balance (Abrams et al 1997, Andon et al 1996, Lonnerdal 1995, Sojka et al 1997). However, high intakes of zinc at 142 mg/day reduce absorption (Spencer et al 1994b). Protein may also influence magnesium absorption. When protein intake is less than 30 g/day (Hunt & Schofield 1969), magnesium absorption decreases. When protein intake is greater than 94 g/day, renal magnesium excretion may increase (Mahalko et al 1983), although adaptation may occur.

The kidney plays a central role in magnesium homeostasis through active reabsorption that is influenced by the sodium load in the tubules and possibly acid-base balance (Quarme & Disks 1986). High dietary calcium intake (about 2,600 mg/day) with high sodium intake enhances magnesium output (Greger et al 1981), contributing to a shift to negative magnesium balance (Kesteloot & Joosens 1990, Quarme et al 1986).

Pathological effects of primary nutritional deficiency of magnesium occur only rarely in humans, unless low intakes are accompanied by prolonged diarrhoea or excessive urinary loss. The body is generally protected by the lability of serum magnesium. Most of the early signs of deficiency are neurologic or neuromuscular defects (Shils 1969, 1988) that may develop with time into anorexia, nausea, muscular weakness, lethargy, weight loss, hyper-irritability, hyper-excitability, muscular spasms, tetany and finally convulsions.

Hypocalcaemia also occurs in moderate to severe magnesium deficiency. Some studies have indicated that low magnesium status may be a risk for postmenopausal osteoporosis (Abraham & Grewal 1990, Reginster et al 1989, Sojka & Weaver 1995, Stendig-Lindberg et al 1993, Tucker et al 1995, Yano et al 1985), however others have not confirmed the link between low magnesium and risk of osteoporosis (Angus et al 1988, Freudenheim et al 1986). Sub-optimal magnesium status may be a factor in the aetiology of coronary heart disease and hypertension, but evidence is relatively sparse (Elwood 1994). Magnesium depletion has been shown to cause insulin resistance and impaired insulin secretion (Paolissa et al 1990), and magnesium supplements have been reported to improve glucose tolerance and insulin response in the elderly (Paolissa et al 1989, 1992).

Indicators used for estimating magnesium requirements have included serum magnesium, plasma ionised magnesium, intracellular magnesium, magnesium balance, estimates of tissue accretion in growth, magnesium tolerance tests and epidemiologic studies including meta-analysis. However, serum magnesium has not been properly validated as a reliable indicator of body magnesium status (Gartside & Glueck 1995). Plasma ionised magnesium may be an improvement on serum magnesium but requires further evaluation and the validity evidence for intracellular magnesium is limited. Magnesium balance is problematic if not carried out under close supervision, as magnesium in water can confound results, a factor that precluded the use of many early studies conducted in free-living situations or current studies where intakes were calculated, not analysed.

Accurate estimates of tissue accretion during growth throughout childhood are dependent on more extensive information about whole body mineral retention than are currently available, although there is some information for specific ages from cadaver data (Fomon & Nelson 1993, Koo & Tsang 1997). The magnesium tolerance test is an invasive procedure based on renal excretion of parenterally administered magnesium load. It is considered accurate for adults but not infants and children (Gullestad et al 1992, Ryzen et al 1985). The test requires normal renal handling and may be unreliable in diabetics or drug or alcohol users. It may also be affected by ageing of kidney tissue (Gullestad et al 1994). Epidemiological studies with meta-analysis may indicate relationships between magnesium intake and health outcomes.

1 mmol magnesium = 24.3 mg magnesium

RECOMMENDATIONS BY LIFE STAGE AND GENDER

<i>Infants</i>	AI	Magnesium
0–6 months	30 mg/day	
7–12 months	75 mg/day	

Rationale: The AI for 0–6 months was calculated by multiplying the average intake of breast milk (0.78 L/day) by the average concentration of magnesium in breast milk (34 mg/L) from 10 studies reviewed by Atkinson et al (1995), and rounding (FNB:IOM 1997). Magnesium is somewhat less bioavailable in formula based on cow's milk but most formulas have higher magnesium content than found in human milk and should be adequate. The AI for 7–12 months was set by adding an estimate for magnesium from breast milk at this age to an estimate of intake from supplementary foods. A breast milk volume of 0.6 L/day (Dewey et al 1984, Heinig et al 1993) and the average magnesium concentration of breast milk of 34 mg/L (Atkinson et al 1995) gives a contribution of 20 mg/day from breast milk which is added to 55 mg/day from complementary foods (Specker et al 1997).

<i>Children & adolescents</i>	EAR	RDI	Magnesium
All			
1–3 yr	65 mg/day	80 mg/day	
4–8 yr	110 mg/day	130 mg/day	
Boys			
9–13 yr	200 mg/day	240 mg/day	
14–18 yr	340 mg/day	410 mg/day	
Girls			
9–13 yr	200 mg/day	240 mg/day	
14–18 yr	300 mg/day	360 mg/day	

Rationale: In the absence of adequate balance and usual accretion data in children aged 1–8 years, data were interpolated from other groups based on body weight change and linear growth (FNB:IOM 1997) that indicate that a magnesium intake of 5 mg/kg a day meets most but not all the needs of those evaluated. This was the basis for the EAR for children 1–8 years. At 1–3 years, with a reference weight of 13 kg, the EAR is 65 mg. For 4–8 years with a reference weight of 22 kg, it is 110 mg/day.

The CV was assumed to be 10%, giving an RDI of 80 mg/day for 1–3 year olds and 130 mg/day for 4–8 year olds. The studies of Abrams et al (1997), Andon et al (1996), and Greger et al (1979) showed that the magnesium requirement per kilogram was the same for boys and girls at this age. Based on the reference weight of 40 kg for both boys and girls, this gives an EAR of 200 mg/day for each gender that, with a CV of 10% for the EAR gives RDIs of 240 mg/day.

The average magnesium requirement is slightly higher for older adolescents because of the increase in growth rate at this age (Abrams et al 1997, Andon et al 1996, Greger et al 1978, 1979, Schwartz et al 1973). The amount required is 5.3 mg/kg for both boys and girls, giving an EAR of 340 mg for boys aged 14–18 years with a standard weight 64 kg and 300 mg for girls aged 14–18 years with a standard weight of 57 kg. Assuming a CV of 10% for the EAR, this gives an RDIs for boys and girls of this age of 410 mg/day and 360 mg/day, respectively.

Adults	EAR	RDI	Magnesium
Men			
19–30 yr	330 mg/day	400 mg/day	
31–50 yr	350 mg/day	420 mg/day	
51–70 yr	350 mg/day	420 mg/day	
>70 yr	350 mg/day	420 mg/day	
Women			
19–30 yr	255 mg/day	310 mg/day	
31–50 yr	265 mg/day	320 mg/day	
51–70 yr	265 mg/day	320 mg/day	
>70 yr	265 mg/day	320 mg/day	

Rationale: The EARs for adults were based on the assumption that the best indicator of adequacy currently available is the level that allows an individual to maintain total body magnesium over time (FNB:IOM 1997). Based primarily on the studies of Greger & Baier (1983), Kelsay & Prather (1983), Kelsay et al (1979), Lakshmanan et al (1984), Mahalko et al (1983), Schwartz et al (1986), Spencer et al (1994a) and Wisker et al (1991) the EARs for adult males are estimated to be 330 mg/day for ages 19–30 years and 350 mg/day at all other ages. Those for adult females are 255 mg/day at 19–30 years and 265 mg/day at all other ages. Assuming a CV of 10% for the EAR, the RDIs are 400 mg/day and 310 mg/day, respectively, for adult men and women aged 19–30 years and 420 mg/day and 320 mg/day, respectively, for men and women aged 31 and over.

Pregnancy	EAR	RDI	Magnesium
14–18 yr	335 mg/day	400 mg/day	
19–30 yr	290 mg/day	350 mg/day	
31–50 yr	300 mg/day	360 mg/day	

Rationale: As there are no direct studies of needs in pregnancy, the EARs and RDIs for pregnancy were based on a consideration of the added lean body mass in pregnancy, assumed to be a mean of 7.5 kg (IOM 1991), a magnesium content of the additional lean body mass of 470 mg (Widdowson & Dickerson 1964) and an adjustment factor of 2.5 for a bioavailability of 40% (Abrams et al 1997). This gives an additional requirement of 35 mg in pregnancy (FNB:IOM 1997) as estimated from $(7.5 \text{ kg}/270 \text{ days}) \times 470 \text{ mg/kg} \times 2.5 = 33 \text{ mg}$, rounded to 35 mg. A CV of 10% for the EAR was assumed to derive the RDI.

Lactation	EAR	RDI	Magnesium
14–18 yr	300 mg/day	360 mg/day	
19–30 yr	255 mg/day	310 mg/day	
31–50 yr	265 mg/day	320 mg/day	

Rationale: The EARs and RDIs for lactation were based on the results of one study of lactating women which showed no effect of lactation on magnesium balance (Dengel et al 1994) and another showing no difference in urinary magnesium between lactating and never-pregnant women consuming diets containing about 270 mg magnesium/day (Klein et al 1995). These studies and a third assessing the blood magnesium status of lactating women (Moser et al 1983) indicate that there is decreased urinary secretion and naturally increased bone resorption in lactation that is independent of diet and appears to provide the necessary additional magnesium without the need for increased dietary intake (FNB:IOM 1997). Thus the EAR and RDI for lactation are the same as for non-pregnant women.

UPPER LEVEL OF INTAKE - MAGNESIUM (as a supplement)

Infants

0–12 months **Not possible to establish. Source of intake should be breast milk, formula and food only.**

Children and adolescents

1–3 yr 65 mg /day
 4–8 yr 110 mg/day
 9–13 yr 350 mg/day
 14–18 yr 350 mg/day

Adults 19+ yr

Men 350 mg/day
 Women 350 mg/day

Pregnancy

14–18 yr 350 mg/day
 19–50 yr 350 mg/day

Lactation

14–18 yr 350 mg/day
 19–50 yr 350 mg/day

Rationale: There are few reports to assist in setting ULs for magnesium, as it has not been shown to produce toxic effects when ingested as naturally occurring magnesium in food. Diarrhoea was selected as the critical endpoint as it is the first sign of excess intake (FNB:IOM 1997). For children and adolescents 8 years and older and adults, a LOAEL of 360 mg of magnesium from non-food sources was established based on the results of Bashir et al (1993), supported by the findings of Fine et al (1991),

Marken et al (1989) and Ricci et al (1991). A UF of 1.0 was selected as diarrhoea is an adverse effect readily apparent to the sufferer. A UL of 350 mg from non-food sources was set for children over 8 years and adults including pregnant and lactating women. It was not possible to set a UL for supplements for infants on existing data, but the figure for children 1–8 years was set by extrapolation from older groups on a body weight basis at a level of 5 mg/kg/day.

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