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

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PHOSPHORUS

BACKGROUND

Phosphorus is the second most abundant inorganic element in the body and is a part of many important compounds, including deoxyribonucleic acid (DNA), ribonucleic acid (RNA), (S)-2-amino-3-[5-tert-butyl-3-(phosphonomethoxy)-4-isoxazolyl]propionic acid (ATPO), adenosine diphosphate (ADP), phospholipids and sugar phosphates. Phosphorus as phosphate is a major buffer of acid in urine by virtue of its monovalent, divalent and trivalent forms. Phosphate helps to protect blood systemic acid/base balance, acts as a temporary store and transport mechanism for energy and helps in activating catalytic proteins. Eighty-five per cent of the body's phosphorus is in bone and the remainder is distributed through soft tissues (Diem 1970).

Inorganic phosphorus is only a tiny fraction of total body phosphorus but plays a critical role in blood and extracellular fluids. Phosphate enters the organic pool after absorption from the diet and resorption from bone. All urinary phosphorus and bone mineral phosphate are derived from the organic pool. Some phosphorus is absorbed with organic compounds such as peptides and lipids, but it is difficult to assess the relative amounts of inorganic and organic phosphorus consumed.

Phosphorus is widely distributed in natural foods and also found in food additives as phosphate salts, used in processing for retaining moisture, smoothness and binding. Most food sources are relatively bioavailable with the exception of plant seeds (beans, peas, cereals, nuts) that contain a special storage form of phosphate called phytic acid. Mammals are generally unable to hydrolyse and use phytate, although some foods also contain the enzyme phytase, as do colonic bacteria, which can release some phosphate from phytate. For adults, bioavailability estimates range from 55 to 70% (Lehmann 1996, Nordin 1989, Stanbury 1971).

Net phosphorus absorption is a linear function of phosphorus intake, indicating that diffusion is the main means of absorption. For infants, bioavailability is highest from human milk (85–90%), followed by cow's milk (72%) and soy formulas (about 59%). However, cow's milk and soy-based infant formulas generally contain substantially more phosphorus than human milk. As a result, phosphorus absorption for infants fed cow's milk and soy formulas appears to be almost twice that of infants fed human milk (Moya et al 1992).

Inadequate intakes or malabsorption of phosphorus as seen in vitamin D deficiency results in hypophosphataemia the symptoms of which include anorexia, anaemia, muscle weakness, bone pain, rickets, osteomalacia, general debility, increased susceptibility to infection, paresthesias, ataxia, confusion and possibly death (Lotz et al 1968). Phosphorus is so widespread in the food supply that dietary phosphorus deficiency is extremely rare, the exception being long-term, severe food restriction.

In the past, a great deal of emphasis was placed on the calcium:phosphorus ratio (Ca:P) of diets (Chinn 1981), particularly those of infants (Fomon & Nelson 1993). This is a useful concept during periods of rapid growth but has little relevance in adults when assessing requirements. Also, the ratio does not take into account differing bioavailabilities and adaptive responses of the two nutrients. In balance studies in human adults, Ca:P molar ratios ranging from 0.08 to 2.4 (a 30 fold range) had no effect on either calcium balance or absorption (Heaney & Recker 1982, Spencer et al 1965, 1978). For this reason, other indicators are now used to assess phosphorus requirements, including measurement of inorganic phosphorus in serum (serum P_i) or phosphorus balance.

As phosphorus intake directly affects serum P_i and because both hypo-and hyperphosphataemia directly cause dysfunction, serum P_i is seen as the best indicator of nutritional adequacy of phosphorus intake. Results of phosphorus balance studies can reflect changes occurring in the body in addition to dietary intake of phosphorus and, as such, are of limited use.

1 mmol phosphorus = 31 mg phosphorus

RECOMMENDATIONS BY LIFE STAGE AND GENDER

Infants	**AI**	**Phosphorus**
0–6 months	**100 mg/day**	
7–12 months	**275 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 phosphorus in breast milk (124 mg/L) from 10 studies reviewed by Atkinson et al (1995), and rounding (FNB:IOM 1997). The AI for 7–12 months was set by adding an estimate for phosphorus from breast milk at this age to an estimate of intake from supplementary foods. A breast milk volume of 0.60 L/day (Dewey et al 1984, Heinig et al 1993) and the average concentration of phosphorus in breast milk at this age 124 mg/L (Atkinson et al 1995) give a contribution of 75 mg phosphorus/day from breast milk that is added to 200 mg/day from complementary foods (Specker et al 1997).

Children & adolescents	**EAR**	**RDI**	**Phosphorus**
All			
1–3 yr	**380 mg/day**	**460 mg/day**	
4–8 yr	**405 mg/day**	**500 mg/day**	
Boys			
9–13 yr	**1,055 mg/day**	**1,250 mg/day**	
14–18 yr	**1,055 mg/day**	**1,250 mg/day**	
Girls			
9–13 yr	**1,055 mg/day**	**1,250 mg/day**	
14–18 yr	**1,055 mg/day**	**1,250 mg/day**	

***Rationale*:** In the absence of data on serum P_i or phosphorus balance in children from 1–8 years, estimation of body accretion for these age groups was used on known tissue composition and growth rates (Fomon et al 1982, FNB:IOM 1997) using a conservative estimate of phosphorus absorption of 70%. The equation used was EAR = (accretion + urinary loss) divided by fractional absorption. This gave an EAR of 380 mg for children aged 1–3 years which, with an assumed CV of 10% for the EAR and rounding, gives an RDI of 460 mg/day. For children aged 4–8 years, the EAR and the RDI were estimated to be 405 mg/day and 500 mg/day, respectively. For 9–13 year olds, longitudinal data and a large cross-sectional database (Slemenda et al 1994) allowed estimation of phosphorus requirement from tissue accretion data using a factorial approach (FNB:IOM 1997) that was then also adopted for the 14–18-year-olds. The EAR for both age groups was set at 1,055 mg/day. Assuming a CV of 10% for the EAR and rounding gave an RDI of 1,250 mg.

Adults	EAR	RDI	Phosphorus
Men			
19–30 yr	**580 mg/day**	**1,000 mg/day**	
31–50 yr	**580 mg/day**	**1,000 mg/day**	
51–70 yr	**580 mg/day**	**1,000 mg/day**	
>70 yr	**580 mg/day**	**1,000 mg/day**	
Women			
19–30 yr	**580 mg/day**	**1,000 mg/day**	
31–50 yr	**580 mg/day**	**1,000 mg/day**	
51–70 yr	**580 mg/day**	**1,000 mg/day**	
>70 yr	**580 mg/day**	**1,000 mg/day**	

***Rationale*:** Using a graphical transformation technique (Nordin 1990, FNB:IOM 1997), the EAR for adults was based on average dietary intake of phosphorus required from a typical mixed diet to reach the lowest point of the normal range for serum P_i (Nordin 1976, 1989). The estimates assume an absorption efficiency of 62.5% (Heaney & Recker 1982, Stanbury 1971, Wilkinson 1976). By definition, at this level of intake, only half the population will achieve a P_i above the bottom of the normal range. A CV of 35% for the EAR was derived from consideration of the increase in ingested intake required to raise serum P_i from the bottom end of the normal range to a level of 3.1 mg/dL (1 mmol/L), the fasting level attained by most well nourished adults (Nordin 1976, 1989, FNB:IOM 1997) giving an RDI of 1,000 mg.

Pregnancy	EAR	RDI	Phosphorus
14–18 yr	**1,055 mg/day**	**1,250 mg/day**	
19–30 yr	**580 mg/day**	**1,000 mg/day**	
31–50 yr	**580 mg/day**	**1,000 mg/day**	

***Rationale*:** As there are no direct studies showing increased needs in pregnancy, the EAR and RDI were set at those of the non-pregnant state.

Lactation	EAR	RDI	Phosphorus
14–18 yr	**1,055 mg/day**	**1,250 mg/day**	
19–30 yr	**580 mg/day**	**1,000 mg/day**	
31–50 yr	**580 mg/day**	**1,000 mg/day**	

***Rationale*:** Increased bone resorption and decreased urinary excretion occurring independently of dietary intake provide the additional needs for milk production (Kent et al 1990, 1991) and thus there is no evidence of increased needs in lactation. Therefore the EAR and RDI are set at those of the non-pregnant state.

UPPER LEVEL OF INTAKE - PHOSPHORUS

Infants	
0–12 months	**Not possible to establish. Source of intake should be through naturally occurring food sources and formula only.**
Children and adolescents	
1–3 yr	**3,000 mg/day**
4–8 yr	**3,000 mg/day**
9–13 yr	**4,000 mg/day**
14–18 yr	**4,000 mg/day**
Adults	
19–70 yr	**4,000 mg/day**
>70 yrs	**3,000 mg/day**
Pregnancy	
14–50 yr	**3,500 mg/day**
Lactation	
14–50 yr	**4,000 mg/day**

***Rationale*:** The UL is set at the intake associated with the upper boundary of normal values of serum P_i. The upper boundaries are higher in infants than in adults and there is no evidence that intakes at the adult upper boundary cause harm. The higher boundaries in infants are obviously tissue-safe and assuming they approximate the upper normal human value, the corresponding ingested intake in an adult would be more than 10,000 mg/day. A NOAEL of 10,000 mg/day was therefore set (FNB:IOM 1997). Information concerning adverse effects in the area between normal P_i and levels associated with ectopic mineralisation is lacking. In keeping with pharmacokinetic practice when relationships between intake and blood level are known (Petley et al 1995), a UF of 2.5 was chosen, taking the UL for adults to 4,000 mg/day. For adults over 70 years, because of increased prevalence of kidney damage, a larger UF of 3.3 was applied, giving a UL of 3,000 mg/day. In pregnancy, absorption efficiency rises by about 15% so the UL was set 15% lower at 3,500 mg/day. In lactation, phosphorus metabolism is the same as in the non-pregnant state, so the UL stays at 4,000 mg/day.

For children, an upper level of intake of 3,000 mg/day was set by dividing the NOAEL for adults by an uncertainty factor of about 3.3 for potentially increased susceptibility related to smaller body size. For children, 9–18 years, the adult UL was applied as there was no evidence to suggest increased susceptibility.

No harm is known to result if dietary phosphorus intakes go above these limits, as may occur for some groups in the community, especially those with high energy intakes.

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