Selenium

Background

Selenium is an essential trace mineral that plays a critical role in human health through its incorporation into selenoproteins, which are involved in a range of biological processes including antioxidant defence, thyroid hormone metabolism and immune function (Alexander & Olsen 2023; Rayman 2012).

In Australia and New Zealand, the highest dietary concentrations of selenium are found in Brazil nuts, seafood, meat and eggs (FSANZ 2022; Ministry for Primary Industries 2018). Other sources of selenium include cereal or grain-based products and dishes (ABS 2011; Ministry for Primary Industries 2018). The selenium content of both cereal-based foods and food from animal sources is influenced by soil selenium concentrations, which vary widely across Australia and New Zealand. This results in geographic differences in dietary selenium intake from locally grown foods (Daniels 2004; Lymbury et al. 2008; Mehdi et al. 2013; Tinggi 2003).

Selenium exists in several organic and inorganic chemical forms, with selenomethionine making up around 90% of the selenium in plants and selenocysteine being the primary form in animal products. Forms of inorganic selenium, predominantly selenate and selenite, are most frequently used in supplements (Burk & Hill 2015). Currently, there are no requirements to add selenium to foods (except infant formula) in Australia and New Zealand (Australian Government 2021). Selenium (as selenomethionine, sodium selenate, or sodium selenite) is permitted to be added to formulated beverages, meal replacements, supplementary sports foods and foods for special medicinal purposes (Australian Government 2025). To support infant nutritional requirements, selenomethionine is also added to infant formula (Australian Government 2025).

Selenium is readily absorbed from the diet, with organic forms such as selenomethionine absorbed more efficiently than inorganic forms. Absorption occurs primarily in the duodenum and is not influenced by selenium status. Once absorbed, selenium is transported to the liver where it is metabolised to selenide - a key intermediate in selenium metabolism (Alexander & Olsen 2023; Lei et al. 2022). Depending on the individual's selenium status, selenide is either converted to selenocysteine for incorporation into selenoproteins or transformed into excretory metabolites via methylation pathways. Selenium excretion varies according to the

amount and form ingested, as well as nutritional status, with urine being the primary route of elimination. Additional losses may occur via faeces and, at high intakes, through expired air (Alexander & Olsen 2023; Lei et al. 2022).

The most widely studied selenoproteins are glutathione peroxidases, selenoprotein P, iodothyronine 5'-deiodinases and thioredoxin reductases (Gladyshev et al. 2016). Glutathione peroxidases are a large family of enzymes that function throughout the body or in specific tissues including the kidney, gastrointestinal tract, plasma and testes. These selenoproteins serve a critical antioxidant function by reducing harmful peroxides such as hydrogen peroxide and lipid peroxides, thereby protecting cells from oxidative damage (Moghadaszadeh & Beggs 2006). Thioredoxin reductases and selenoprotein P also protect against oxidative injury, in addition to contributing to cell growth, ascorbate (vitamin C) recycling and the transport of selenium from the liver to peripheral tissues (Burk et al. 2003; Mustacich & Powis 2000). Selenium also supports thyroid hormone regulation through iodothyronine 5'-deiodinases, which catalyse the conversion of prohormone thyroxine (T_4) to its active form, triiodothyronine (T_3).

Selenium deficiency can affect multiple body systems, including cardiovascular, musculoskeletal, reproductive and immune systems, and has been linked to a range of conditions (Shreenath et al. 2023; Wang et al. 2023). Certain population groups may be at increased risk, including individuals living in regions with low soil selenium concentrations (Daniels 2004), cigarette smokers (Park et al. 2011; Thomson 2004), and those with inflammatory conditions (Duntas & Hubalewska-Dydejczyk 2015; Huang et al. 2012). Several endemic diseases have been specifically associated with severe selenium deficiency, particularly in geographic regions with low soil selenium. Keshan disease is an endemic cardiomyopathy identified in low selenium regions in China, primarily affecting children and women of reproductive age. Symptoms include cardiac enlargement, heart failure, arrhythmias and premature death. Sodium selenite supplementation and nutrition policy implementation have significantly reduced prevalence, though other factors are thought to contribute to Keshan disease pathogenesis, including viral infection, malnutrition and genetic factors (Chen 2012; Loscalzo 2014; Yan et al. 2021). Similarly, Kashin-Beck disease, a degenerative joint condition linked to selenium deficiency, is prevalent in Tibet, China, Siberia and North Korea (Shreenath et al. 2023).

Selenium excess is less common, and no evidence of any specific populations being more susceptible to selenium excess has been identified. However, habitual consumption of Brazil nuts (due to their high concentration of selenium) or excess consumption of selenium-containing supplements could lead to excess in some

individuals. Symptoms of acute selenium toxicity (selenosis) include nausea, vomiting, abdominal pain, tremors, and muscle spasm, while chronic exposure may lead to alopecia (hair loss), brittle hair and nails, tooth discolouration, and neurological symptoms such as fatigue and weakness (Nuttall 2006). Some studies suggest that high selenium intake may raise the risk of type 2 diabetes, but findings are inconsistent, and not strong enough to confirm a direct link (Lippman et al. 2009; Stranges et al. 2007; Thompson et al. 2016).

Numerous clinical trials have investigated selenium's potential role in preventing prostate, lung, and colorectal cancers (Clark et al. 1996; Lippman et al. 2009; Reid et al. 2002), but more recent meta-analyses have found insufficient evidence to support this link (Turck et al. 2023; Vinceti et al. 2018). Notably, a large, randomised placebo-controlled trial involving approximately 35,000 men found no association between selenium supplementation and reduced prostate cancer risk (Lippman et al. 2009). Assessment of selenium intake can be conducted using various biomarkers, with serum or plasma selenium concentrations being the most robust and commonly used, though they may be less sensitive to inorganic selenium in selenium-replete populations (Ashton et al. 2009; Turck et al. 2023). Urinary selenium is useful for short-term intake assessment, while toenail and hair concentrations reflect long-term status. Functional biomarkers such as glutathione peroxidases and selenoprotein P are also employed, though their reliability may be limited to lower intake ranges and influenced by oxidative stress. Importantly, all selenium biomarkers are affected by physiological and lifestyle factors including sex, age, and disease status (Turck et al. 2023).

1 mmol selenium = 79 mg selenium

Recommendations by Life Stage and Sex

The following Nutrient Reference Values for selenium have been established for the Australian and New Zealand populations. These recommendations are based on the best available scientific evidence and are designed to meet the nutritional needs of healthy individuals across different life stages while minimising the risk of both deficiency and excess intake.

Infants

Age	AI (µg/day)
0-6 months	12
7-12 months	15

Abbreviations: AI, Adequate Intake

Rationale: The Adequate Intake (AI) for 0–6 months was calculated by multiplying together average breast milk intake (0.78 L/day) and average breast milk selenium concentration (15 µg/L) in Australia and New Zealand, and rounding to the nearest whole number (Cumming et al. 1992; Daniels et al. 2000; Dolamore et al. 1992) The AI for 7–12 months was then extrapolated from younger infants using metabolic weight.

Children & Adolescents

This table summarises Estimated Average Requirement (EAR) and Recommended Dietary Intake (RDI) recommendations for children and adolescents in different age groups and sexes based on extrapolation from adult values. *For alternative children's age groups aligned with National Nutrition Survey data or school-age groups, see Attachment 1.*

Age	EAR (µg/day)	RDI (µg/day)
Both sexes		
1 to under 4 years	20	25
4 to under 9 years	25	30
9 to under 14 years	40	50
Males		
14 to under 18 years	60	70
Females		
14 to under 18 years	50	60

Abbreviations: EAR, Estimated Average Requirement; RDI, Recommended Dietary Intake.

Rationale: The EAR for children was extrapolated from the adult data using scaling based on metabolic weight and rounded to the nearest 5 µg. The RDI was derived, assuming a coefficient of variation (CV) of 10% for the unrounded EAR.

Adults

This table provides recommendations for adults by sex and life stage.

Age	EAR (µg/day)	RDI (µg/day)
Males		
18 to under 30 years	60	70
30 to under 50 years		
50 to under 65 years		
65 to under 75 years		
75 years and older		
Females		
18 to under 30 years	50	60
30 to under 50 years		
50 to under 65 years		
65 to under 75 years		
75 years and older		

Abbreviations: EAR, Estimated Average Requirement; RDI, Recommended Dietary Intake.

Rationale: Adult EARs were based on experimental data that assessed GP_X (glutathione peroxidase) activity at various supplemental selenium intakes, with the findings corrected to reference adult body weights (Duffield et al. 1999; Xia et al. 2005). The RDI was derived, assuming a coefficient of variation (CV) of 10% for the unrounded EAR. Both EAR and RDI were rounded up to the nearest 5 µg to obtain the final recommendations.

Pregnancy

Age	EAR (µg/day)	RDI (µg/day)
Pregnancy (all ages)	55	65

Abbreviations: EAR, Estimated Average Requirement; RDI, Recommended Dietary Intake.

Rationale: Studies suggest that selenium intake requirements increase between 1-4 µg/day during pregnancy (Casey et al. 1982; FAO:WHO 2001; Oster et al. 1988; Schroeder et al. 1970; Zachara et al. 2001). Additionally, increased nutrient requirements during pregnancy may result in an adaptive increase in absorption (Department of Health 1991; Netherlands Food and Nutrition Council 1989; Scientific Committee for Food 1993). Considering these findings, 2 µg was added to the EAR for adult women, and the value rounded up to the nearest 5 µg. The RDI was derived, assuming a CV of 10% for the unrounded EAR.

Lactation

Age	EAR (µg/day)	RDI (µg/day)
Lactation (all ages)	65	75

Abbreviations: EAR, Estimated Average Requirement; RDI, Recommended Dietary Intake.

Rationale: The EAR for lactation includes an allowance of 12 µg/day for selenium secreted in breast milk, which is added to requirements. The RDI was derived, assuming a coefficient of variation (CV) of 10% for the unrounded EAR. Both EAR and RDI were rounded up to the nearest 5 µg to obtain the final recommendations.

Upper Level of Intake

These tables summarise upper levels (ULs) for children and adolescents in different age groups and sexes based on extrapolation from adult values. *For alternative children's age groups aligned with national nutrition survey intake data or school-age groups, see Attachment 1.*

Age	UL (µg/day)
Infants	
0–6 months	45
7–12 months	60
Children & Adolescents	
1 to under 4 years	100
4 to under 9 years	150
9 to under 14 years	235
14 to under 18 years	305
Adults	

18 years and older	330
Pregnancy & Lactation	
Pregnancy (all ages)	330
Lactation (all ages)	330

Abbreviations: UL, Upper Level.

Rationale: The UL for adults was based on data from a large randomised controlled trial of selenium supplementation (200 µg/day) versus placebo in healthy men aged over 50 years in the USA, with a median follow-up of 5.5 years (Lippman et al. 2009). At average selenium intakes of 330 µg/day (approximately 130 µg/day from the background diet and 200 µg/day from supplements), the risk of developing alopecia was increased compared to unsupplemented individuals with similar background selenium intakes. From this finding, a LOAEL (Lowest Observed Adverse Effect Level) of 330 µg/day was identified as the reference point. Alopecia was selected as the critical effect as it is a well-established, early observable indicator of excess selenium intake.

An uncertainty factor (UF) of 1 was applied to the reference point based on expert judgement. This decision was informed by the high quality and currency of the evidence base, the practicality of the resulting UL relative to recommended intake levels and population intake estimates, and the absence of evidence demonstrating adverse effects at selenium intakes below 330 µg/day. The UL for adults (including during pregnancy and lactation) was therefore established at 330 µg/day.

ULs for children were extrapolated from the adult UL using allometric scaling based on reference body weights.

Upper Levels for infants were derived from a study demonstrating a lack of adverse effects at concentrations of 60 µg/L in human breast milk (Shearer & Hadjimarkos 1975). This yields a NOAEL (No Observed Adverse Effect Level) of 47 µg/day (7 µg/kg body weight), to which an UF of 1 was applied, reflecting the lack of evidence that maternal intakes associated with human milk in this range cause toxicity for mothers or infants.

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Attachment 1 — Alternative age groups for children

To align with reporting age groups in the Australian Bureau of Statistics (ABS) National Nutrition Survey, ages have also been grouped to provide levels for preschoolers (2 to under 5 years), primary school age (5 to under 12 years) and adolescents (12 to under 18 years). The derivation of these values used the same methodology as outlined in the document above and is based on the same adult reference value. If you are not comparing to National Nutrition Survey data or school-age groups, use the values for children and adolescents in the main document above.

Recommendations

Alternative age groups for preschool, primary school and adolescents.

Age	EAR (µg/day)	RDI (µg/day)
Both sexes		
12 to under 24 months	20	25
2 to under 5 years	20	25
5 to under 12 years	30	40
Males		
12 to under 18 years	55	65
Females		
12 to under 18 years	45	55

Abbreviations: EAR, Estimated Average Requirement; RDI, Recommended Dietary Intake.

Upper Level of Intake

Alternative age groups for preschool, primary school and adolescents

Age	UL (µg/day)
Both sexes	
12 to under 24 months	85
2 to under 5 years	120
5 to under 11 years	185
12 to under 18 years	295

Abbreviations: UL, Upper Level.