Evidence Summary Report

Summary of the evidence used to inform development of Selenium Upper Levels of Intake for Australia and New Zealand Nutrient Reference Values

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Contents

Purpose

This report has been prepared to inform the process of updating the National Health and Medical Research Council's (NHMRC) selenium Upper Level of Intake (UL) by adopting or adapting the 2023 selenium UL developed by the European Food Safety Authority (EFSA). It aims to summarise evidence for consideration by the Steering Group Advisory Committee alongside existing evidence sources, including the following:

- Evidence reviews commissioned or conducted by comparable international bodies for the purposes of establishing a selenium UL:
    - EFSA (2023) - *Scientific opinion on the tolerable upper intake level for selenium*
    - Alexander and Olsen (2023) – *Selenium: a scoping review for Nordic Nutrition Recommendations 2023*
- Other reports published by key international bodies relevant to establishing selenium nutrient reference values:
    - UK SACN (2013) - *Position Statement on Selenium and Health*
    - FAO & WHO Codex nutrient reference values (Lewis 2019)
- Primary evidence or data relevant to the Australian and New Zealand context.

Rationale for prioritising this update

In 2006, NHMRC published its current Nutrient Reference Values (NRVs) for selenium (NHMRC 2006). These values were adopted from the US Institute of Medicine's Dietary Reference Intakes for selenium (IOM 2000).

In 2023, EFSA updated their UL for selenium (EFSA 2023) based on a large, high-quality randomised controlled trial (RCT) (Lippman et al. 2009). NHMRC recently updated their health-based guideline value for selenium levels in drinking water (NHMRC 2025a) based on the same RCT (Lippman et al. 2009).

To save resources and minimise duplication of effort, NHMRC was seeking to pilot a process for updating NRVs by adopting or adapting recommendations from other comparable jurisdictions. This approach is in line with the international NRV community's efforts towards harmonising methods and sharing resources. Updating the selenium UL was an opportunity to develop and test these

methods and achieve greater consistency in selenium ULs both within the NHMRC and internationally.

Methods summary

The review of selenium NRVs was conducted in accordance with the Methodological Framework for the Review of Nutrient Reference Values (NHMRC 2025b).

When assessed against predetermined criteria, the 2023 EFSA selenium UL was found to have been developed in a manner consistent with the NHMRC Standards for Guidelines (NHMRC 2016), and was considered suitable for adopting or adapting to the Australian and New Zealand context (see Appendix A). Further evidence was identified to inform the adaptation of EFSA recommendations to the Australian and New Zealand context.

The evidence for benefits and harms- along with other relevant contextual factors- were then weighed and balanced to arrive at final recommendations. Further information about the development of recommendations is provided below and in attachments. Outcomes of this process are presented in a series of Evidence-to-Decision (EtD) frameworks (Appendix B). More detailed information on NHMRC methods for deriving NRVs can be found in the Methodological Framework for the Review of Nutrient Reference Values (NHMRC 2025b).

Governance

Governance processes for the selenium UL reviews comprise:

- a Steering Group, comprising NHMRC, the Department and New Zealand Ministry of Health
- a Steering Group Advisory Committee (Advisory Committee) to advise the Steering Group with selenium experts to provide nutrient-specific advice.

The Steering Group prioritised updating the selenium UL to pilot the adopt/adapt methodology. Throughout the review, the Advisory Committee provided advice on the application of the methodological framework and methods for deriving NRVs, whilst the selenium experts provided technical advice on considerations specific to selenium nutrition. Members' interests were declared and managed in line with NHMRC's Policy on the Disclosure of Interests Requirements for Prospective and Appointed NHMRC Committee Members (NHMRC 2019).

Selenium background

Function, physiology and metabolism

Selenium is an essential trace mineral that occurs naturally in various foods. Selenium is found in all tissues and plays a vital role in various metabolic processes, such as antioxidant activities, thyroid hormone metabolism and DNA synthesis (Alexander & Olsen 2023). It further supports reproductive health and immune function.

Selenium is primarily present as selenomethionine, which is incorporated into several selenoproteins. The most significant of these are glutathione peroxidase (GPx), selenoprotein P, iodothyronine 5'-deiodinase, and thioredoxin reductase (Gladyshev et al. 2016).

Dietary sources of selenium

Food

Food is the primary source of selenium for humans, while drinking water and air contribute only minor amounts (Barceloux 1999). According to Australian food composition data, the following foods are rich sources of selenium; seafood, dried chickpeas, poultry, eggs and muscle meats (Food Standards Australia New Zealand 2022). The food with the highest selenium concentration is Brazil nuts with an average of 575 micrograms (µg) per 30g, followed by mustard powder (48 µg per 30g) and yelloweye mullet (33 µg per 30g) (FSANZ 2022). The Australian Health Survey indicates that meat, poultry, fish, seafood and game products - along with cereal-based products and dishes - are the main dietary contributors to selenium intake for the Australian population, including children and teenagers (ABS 2019).

According to the 2016 New Zealand Total Diet Study, the highest dietary concentrations of selenium were found in mussels, oysters and fresh and canned fish, with intermediate levels found in mushrooms and eggs. Fish, chicken, meat and eggs were the primary dietary sources of selenium across all age and sex groups, while grain-based foods were especially important for infants, children and teenagers (Ministry for Primary Industries 2018).

The selenium content in foods from animal sources varies according to the selenium levels in the animals' diet (Mehdi et al. 2013). The selenium content in plant-based foods varies widely depending on the selenium concentration in the soil where they are grown (Daniels 2004; Tinggi 2003). Soil selenium levels are highly variable in Australia and New Zealand, therefore dietary intake of selenium

from cereal-based foods differ geographically (Lymbury et al. 2008; Thomson 2004). Factors such as soil pH, organic matter, and geographical location can significantly influence the selenium content in these foods (Rayman 2012). Regions with selenium-poor soils, such as parts of Tasmania, may produce foods with lower selenium content, leading to lower overall selenium intake among residents (Beckett & Ball 2011; Jacobson et al. 2007).

Plant and animal sources of dietary selenium occur mainly as the organic compounds selenomethionine and selenocysteine with nearly 90% of selenium in plants present as selenomethionine (Burk & Hill 2015; Fairweather-Tait 1997; Mehdi et al. 2013).

Animal protein sources contain selenoproteins with selenium in the form of selenoscysteine and for fish, selenomethionine or selenoneine are the key forms of selenium depending on the fish species (Lipiec et al. 2010; NHMRC 2006; Sele et al. 2018).

Selenium (in the forms of selenomethionine, sodium selenate or sodium selenite) is permitted to be added to formulated beverages, meal replacements, supplementary sports foods, and foods for special medical purposes. There is no requirement to add selenium to food - except for infant formula - in Australia or New Zealand (Australian Government 2021, 2025c).

Water

Selenium levels in Australian drinking water are typically less than 0.0025 mg/L, except for a small number of remote Northern Territory regions recording mean concentrations up to 0.015 mg/L (SLR 2022, PWNT 2004). Guideline values have recently been reviewed and lowered from 0.01 mg/L to 0.004 mg/L to reflect contemporary evidence (NHMRC 2025a).

Supplements

The 2023-24 Australian National Nutrition and Physical Activity Survey found that 33.6% of people aged two-years and over, and 37.3% of adults (18-years and over) took a dietary supplement in 2023; 15.5% of the population took a multivitamin or multimineral supplement (17.0% for adults), and 0.7% of the population aged two-years and over (0.8% of adults) took an ‘other single mineral supplement’ (ABS 2025). There were no specific figures for the use of selenium-only supplements.

In New Zealand, the 2008–09 Adult Nutrition Survey (University of Otago & Ministry of Health 2011) found that 47.6% of people aged 15-years and over took a supplement in the past year, with 30.7% being regular users; 10.6% of men and 18.6% of women consumed multivitamin and multimineral supplements, 3.0% of men and 8.5% of women consumed single mineral supplements, and 1.0% of men and 2.1% of women consumed multimineral supplements. There are no specific data available regarding the use of selenium-only supplements.

According to the Therapeutic Goods Poisons Standard (Australian Government 2025a, 2025b), selenium is classified as a Schedule 2 (pharmacy medicine) except for oral preparations with a recommended daily dose of 150 µg or less, and as a Schedule 4 (prescription only medicine) for oral human use with a recommended daily dose exceeding 300 micrograms.

Bioavailability factors

Dietary selenium is well absorbed, with absorption not being largely affected by dose or the body's selenium status (Burk & Hill 2015; Lei et al. 2022). The absorption of selenium in the body depends somewhat on its chemical form. While around 70-80% of selenium from major dietary sources is absorbed, only a little over half of it is retained. (Alexander & Olsen 2023).

Various methods have been used to measure selenium bioavailability in foods, including changes in blood (including plasma, serum and erythrocytes) selenium concentration, GPx enzyme activity, and absorption/retention studies using stable isotopes (Fairweather-Tait & Collings 2010). Data on selenium metabolism from various foods and supplements show differences in absorption and utilisation between inorganic and organic forms in humans (Brown et al. 2000; Butler et al. 1991). Plants accumulate inorganic forms of selenium like selenites and selenates through soil and ground water and convert to organic forms like selenomethionine and selenocysteine, with selenomethionine being more readily absorbed and retained than inorganic forms (Hadrup & Ravn-Haren 2021).

While the absorptive pathways are not fully understood, selenium in the form of selenate or selenite is well absorbed but less retained compared to organic forms like selenomethionine and selenocysteine (Burk et al. 2006; Schrauzer 2000). Selenomethionine is absorbed primarily in the duodenum similarly to methionine and is not influenced by selenium status (NHMRC 2006). Most selenium forms are efficiently absorbed, but their metabolism depends on their plasma form. Selenomethionine, selenocysteine, selenate, and selenite enter the selenide pool, where they are either used for selenoprotein synthesis or excreted as selenosugar in the urine (Fairweather-Tait & Collings 2010). One study found that most selenium from meat - assumed to be primarily selenomethionine - is absorbed, with just over half retained in the body (Bügel et al. 2004). Selenium from Brazil nuts showed better utilisation than selenomethionine, as evidenced by similar plasma selenium increases despite lower daily intake (Thomson et al. 2008).

Selenomethionine can also be directly incorporated into proteins by replacing methionine (Fairweather-Tait & Collings 2010). The organic compound γ-glutamyl methylselenocysteine, found in brassica and allium vegetables is metabolised differently (Rayman et al. 2008). It converts to Se-

methylselenocysteine and then to β-lyase into methylselenol, which is mainly excreted in breath and urine but can also enter the selenide pool.

Health effects of excess

Excess selenium

Health effects of excess selenium can present as clusters of symptoms as outlined below for acute and chronic selenosis.

Acute selenosis

Acute selenium poisoning, also known as 'acute selenosis,' presents with symptoms such as low blood pressure (hypotension) and rapid heart rate (tachycardia), along with nausea, vomiting, diarrhoea, abdominal pain, and pulmonary oedema. Neurological symptoms can include tremors, muscle spasms, restlessness, confusion, delirium, and even coma (Fairweather-Tait & Collings 2010; Nuttall 2006).

Chronic selenosis

The most common signs of chronic selenium poisoning, or 'chronic selenosis,' include brittle, thickened nails with white spots and longitudinal streaks, as well as brittle hair and hair loss (alopecia). Other symptoms include tooth discoloration and decay, a garlic odour on the breath, skin lesions, and neurological issues such as fatigue, weakness, peripheral paraesthesia, hyperreflexia, pain in the extremities, unsteady gait, paralysis, and decreased cognitive function (Fairweather-Tait & Collings 2010; NHMRC 2006; Nuttall 2006; Rayman et al. 2008).

Sensitive or at-risk groups

While several population groups are at greater risk of deficiency – including cigarette smokers (Park et al. 2011; Thomson 2004), people living in regions with low soil selenium levels (Daniels 2004) or people with inflammatory conditions (Duntas & Hubalewska-Dydejczyk 2015; Huang et al. 2012)) - no evidence has been identified that suggests any specific groups are at greater risk of selenium excess. 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.

Inflammation

Dietary selenium plays an important role in inflammation and the immune response (Huang et al. 2012) with chronic inflammation thought to deplete selenium stores in the body (Duntas & Hubalewska-Dydejczyk 2015). Adequate selenium levels in the body are important for both initiating immunity and regulating excessive immune responses and chronic inflammation (Huang et al. 2012).

Although inflammatory diseases can decrease selenium levels in the body, it should not be assumed that people with inflammatory disease are selenium deficient, selenium status should be measured before selenium supplementation is recommended to minimise the risk of selenosis in those with adequate-to-high status (Duntas & Hubalewska-Dydejczyk 2015).

Measuring intake or status

Dietary assessment methods

Intake estimates based dietary assessment methods should be interpreted with caution due to potential inaccuracy in both the information provided by participants in 24-hour dietary recall interviews, and in the food composition databases. Under-reporting by participants is common in nutrition surveys due to changes to foods eaten because they know they will be participating in the survey, and misrepresentation (deliberate, unconscious or accidental), to make their diets appear 'healthier' or be quicker to report (social desirability bias). Systematic under-reporting in children can be due to young children's inability to remember what they have eaten, and parents/carers of school-aged children being unaware of a child's food intake while at school.

Limitations of food composition databases include variability in nutrient content of food due to factors such as variety, soil type and season, or changes to formulation or processing practices. For some foods, values cannot be generated from analysed samples and need to be borrowed from overseas food composition tables, supplied by the food industry, taken from food labels, imputed from similar foods, or calculated using a recipe approach [1].

Biomarkers of intake or status

Accurate assessment of selenium intake requires analysing food samples due to geographic variations not captured in standard food tables (Combs 2015). Biomarkers of selenium status can help estimate intake, especially in selenium-deficient individuals, but the relationship between intake and plasma selenium levels varies with the form of selenium consumed (Combs 2015; Combs et al. 2012; Hurst et al. 2010).

A variety of biomarkers are used to assess selenium intake and/or status, each with varying sensitivity and application (Table 1). Among these, serum/plasma concentration is the most widely used and supported by the strongest body of evidence. It is effective for detecting short- to medium-term changes in selenium intake but shows limited sensitivity to inorganic selenium in selenium-replete individuals, and responses to supplementation can vary (Ashton et al. 2009; Turck et al.

[1] https://www.foodstandards.gov.au/science-data/monitoringnutrients/afcd/legal

2023). Erythrocytes can also be used as a biomarker of selenium status (Combs Jr 2015). Urinary selenium is another commonly used biomarker, reflecting short-term intake. While it can distinguish between high and low selenium intakes, the high variability of urinary selenium may limit its reliability. For assessing long-term selenium status, toenail and hair selenium concentrations are used, particularly in observational studies. Selenoproteins such a GPx and selenoprotein P are also employed as functional biomarkers. However, their utility is limited to lower intake ranges (typically below 70 µg/day), and their levels may be influenced by oxidative stress. Notably, all selenium biomarkers are affected by various physiological and lifestyle factors, including age, sex, disease status, inflammation and smoking (see Appendix A; (Turck et al. 2023), and it is important to consider the context and limitations of each measure.

Table 1. Overview of biomarkers of selenium intake and status

Biomarker	Description	Sensitivity as biomarker of selenium intake and status
Serum/plasma selenium concentration	Detects non-cellular selenium, organic selenium, albumin-bound selenomethionine, selenosugars and inorganic selenium (Vinceti et al. 2018)	- Detect changes in intake over short term - Low sensitivity to inorganic selenium intake in selenium-replete populations - Can distinguish individuals with high dietary intake from low intake - Population-specific equations to predict dietary selenium intake (Burk et al. 2006; Combs 2015)
Glutathione peroxidase (GPx) activity	Measurement of the enzymatic activity of GPx isoforms expressed in specific blood compartments, including plasma, platelets, red blood cells or whole blood	- Reaches maximum at activity at intakes of 40-60 µg/day, so is limited to the lower range of selenium intake - Increase in activity can also be attributed to oxidative stress (Turck et al. 2023)
Plasma selenoprotein P concentration	Detects 20-70% of total plasma selenium, mostly secreted in the liver (Saito 2021)	- Responsive in populations with selenium status in the lowest range - Plateaus with selenium intakes of 60-70 µg/day - Similar to GPx, increases in activity can also be attributed to oxidative stress (Turck et al. 2023)
Toenail and hair selenium concentration	Deposits of selenium	- Can detect variations in intake over medium to longer term. Largely used as a measure in observational studies (Alexander & Olsen 2023) - Can distinguish consumers with high vs low intake - Requires standardised procedures for collection of samples and treatments as prone to contamination (Slotnick & Nriagu 2006)
Urinary selenium concentration	- Main route of selenium elimination (Turck et al. 2023) - Can be highly variable, as excess of selenium not going into selenoprotein synthesis or into proteins as selenomethionine is excreted into urine (Alexander & Olsen 2023)	- Can detect variations in intake over the short-term - Can distinguish individuals with high intake from low intake - At a constant dietary intake, plasma selenium and urinary excretion look to be closely related (Burk & Hill 2015).

Current recommendations and international comparisons

Basis for current UL recommendations

The current Australian and New Zealand NRVs for selenium were developed in 2006 and adapted from values published by the US Institute of Medicine (IOM 2000). The UL was based on a study showing an increase in the risk of squamous cell carcinoma and total non-melanoma skin cancer with selenium supplementation of 200 µg/day among individuals at high risk of non-melanoma skin cancer (Duffield-Lillico et al. 2003). An uncertainty factor (UF) of 2 was applied to protect sensitive individuals because of gaps in data and incomplete knowledge, bearing in mind that the toxic effect of selenium was not severe, but may be irreversible. The UL was therefore set at 400 µg/day for all adults, as there was no data available to suggest increased susceptibility during pregnancy and lactation (IOM 2000).

While a review of infant NRVs was not within scope of this review, ULs for children and adolescents were scaled up from infant data. Consequently, the basis for deriving infant values is discussed here for completeness.

The UL for young infants was based on the work of Shearer and Hadjimarkos (1975) showing that human breast milk concentrations of 60 µg/L was not associated with adverse effects. This gives a No Observed Adverse Effect Level (NOAEL) of 47 µg/day (7 µg/kg body weight). A UF of 1 was applied, as there was no evidence that maternal intakes associated with human milk in that range caused toxicity for mothers or infants. There was no evidence of increased toxicity in older children and adolescents, therefore the ULs for these groups were estimated from the younger infant data on a body weight basis, using the level of 7 µg/kg body weight (IOM 2000).

Comparison with international values

Since 2006, several international jurisdictions have published updated ULs for selenium, based on contemporary evidence review methods and more current research. Although there is variation in local context related to population selenium status, dietary patterns and age groups used across jurisdictions, ULs developed using comparable approaches are informative for the purposes of establishing or benchmarking the proposed UL for Australia and New Zealand. The current NHMRC value varies substantially compared with that set by the European Food Safety Authority (EFSA Panel on Nutrition et al. 2023).

The European Food Safety Authority (EFSA)

To develop their UL, EFSA conducted systematic reviews of the literature to identify evidence regarding excess selenium intake and clinical effects, potential biomarkers of effect, risk of chronic diseases and impaired neuropsychological development in humans. A large, high-quality randomised controlled trial in humans (the Selenium and Vitamin E Cancer Prevention Trial (SELECT) (Lippman et al. 2009)) was identified as the best available evidence upon which to base their updated UL. An independent evidence review undertaken to update the 2025 NHMRC water quality guidelines also identified the SELECT trial as the best available evidence upon which to base their updated guidance on selenium levels in drinking water (NHMRC 2025a).

The SELECT trial provided a lowest-observed-adverse-effect-level (LOAEL) of 330 µg/day for selenium, with alopecia as the critical end point. EFSA applied an uncertainty factor of 1.3 to account for the following uncertainties:

- The use of a LOAEL rather than a NOAEL as the reference point (noting that study results indicated that the NOAEL might be close to the LOAEL)
- The lack of data in women.

The result was rounded to the nearest 5 µg/day to establish a UL of 255 µg/day for adult men and women (including pregnant and lactating women; no evidence was found of increased sensitivity for these populations). ULs for children were derived from the UL for adults using allometric scaling (body weight$^{0.75}$).

These values were adopted by the 2023 Nordic Nutrition Recommendations (Blomhoff et al. 2023).

Other jurisdictions

The selenium UL values set by different international jurisdictions are presented in Table 2.

Table 2. International Overview of Upper Levels of Intake (UL) for selenium in µg/day

	Australia & New Zealand	Europe (current)	Europe (previous)	USA	UK	International
Population Group	**NHMRC** (2006)	**EFSA**[a] (2023)	**SCF** (2000)	**IOM** (2000)	**EVM** (2003)[b]	**WHO/FAO** (2004)
Infants						
0-6 months	45		nd	45	nd	nd
4-6 months		45[d]				
7-11 months		55[d]				
7-12 months	60[c]		nd	60[c]	nd	nd
Children & adolescents						
1-3 years	90[c]	70[d]	60[c]	90[c]	nd	nd
4-6 years		95[d]	90[c]		nd	nd
4-8 years	150[c]			150[c]	nd	nd
7-10 years		130[d]	130[c]		nd	nd
9-13 years	280[c]			280[c]	nd	nd
11-14 years		180[d]	200[c]		nd	nd
14-18 years	400[c]			400[c]		
15-17 years		230[d]	250[c]		nd	nd
Adults						
≥ 18 years	400[e]	255[e]	300[e]	400[c]	450	400

Abbreviations - nd: not defined; EVM: UK Expert Group on Vitamins and Minerals (UK); IOM: Institute of Medicine (US); NHMRC: National Health and Medical Research Council of Australia and New Zealand; SCF: Scientific Committee on Food; WHO/FAO: World Health Organization/Food and Agriculture Organization of the United Nations.
(a): Also adopted by Nordic Nutrition Recommendations 2023
(b): Safe upper level (SUL).
(c): Extrapolated from the UL for infants aged 0–6 months (7 µg/kg body weight/day) on a body weight basis.
(d): Extrapolated from the UL for adults on a body weight basis.
(e): Including pregnant and lactating women.

Current recommendations for nutritional requirements

The various UL recommendations of international jurisdictions should be considered relative to the recommendations for ensuring nutritional adequacy. The EFSA Adequate Intake (AI) values for selenium range from 15 µg/day for infants to 70 µg/day for adults and during pregnancy (Table 3). The new EFSA UL for selenium is set at 255 µg/day, approximately 3.6 times the AI for adults (Table 2). Comparing these values to the NHMRC values, the NHMRC NRVs for selenium are generally similar, with values ranging from 12 µg/day for infants to 70 µg/day for adults. The 2006 NHMRC UL for selenium is higher at 400 µg/day for adults, approximately 5.7 times the Recommended Dietary Intake. If the NHMRC were to adopt EFSA's UL of 255 µg/day, it would represent a significant decrease, aligning more closely with EFSA's conservative approach to selenium intake established from the Lippman et al. (2009) endpoint of alopecia and identification of a LOAEL of 330 µg/day. This change would potentially reduce the risk of selenium toxicity and align with research published since

the UL was last reviewed in 2006. The values for other jurisdictions, such as the Institute of Medicine and World Health Organization/Food and Agriculture Organization of the United Nations, have not been updated for over 20 years. The Nordic Nutrition Recommendations were updated in 2023 and the adequate intake Selenium increased across age groups. NNR adopted the EFSA UL.

Table 3. Overview of nutritional adequacy NRVs for Selenium across the lifespan (µg/day)

Population Group	NHMRC (2006)	EFSA (2014)	NNR (2023)	WHO/FAO (2004)	IOM (2000)
Infants					
0-6 months	12 [(a)]	15	10	nd	nd
7-11 months	15 [(a)]	15 [(a)]	20	10	20 [(a)]
Children & adolescents					
1-3 years	20-25	15 [(a)]	20	17	20
4-8 years	25-30	20 [(a)]	25	22	30
7-10 years		35 [(a)]	40	21	
9-13 years (boys)	40-50	55 [(a)]	65	32	40
9-13 years (girls)	40-50	55 [(a)]	60	26	40
14-18 years (boys)	60-70	70 [(a)]	85	32	45
14-18 years (girls)	50-60	70 [(a)]	70	26	45
Adults					
18-65 (males)	60-70	70 [(a)]	90	34	55
18-65 (females)	50-60	70 [(a)]	75	26	55
>65 years (male)			85	33	
>65 years (female)			75	25	
Pregnancy and Lactation					
Pregnancy	55-65	70	80/85/90[(b)]	28/30 [(b)]	14-50
Lactation	65-75	85	85	35/42 [(c)]	70

nd: not defined; NHMRC: National Health and Medical Research Council of Australia and New Zealand; EFSA: European Food Safety Authority; NNR: Nordic Nutrition Recommendations; WHO/FAO: World Health Organization/Food and Agriculture Organization of the United Nations; IOM: Institute of Medicine (US).
(a): Adequate Intake (AI)
(b) 2nd trimester/3rd trimester
(c) 0-6 months post-partum /7-12 months post-partum

Australian and New Zealand context

Population status and intakes

Selenium intake

Intake estimate methods

Nutrient intakes for Australia and New Zealand have been estimated using national nutrition surveys. In these surveys, results of 24-hour dietary recall interviews (food and supplement use for Australia, food only for New Zealand) were applied to national food composition databases to derive estimates of intake for different population groups. Mean and 90th (New Zealand) or 95th (Australia) percentile estimates were calculated for each population group, however, no 95th percentile intake estimates were available for Aboriginal and Torres Strait Islander populations.

Assumptions made about the Australian and New Zealand Nutrition Surveys were:

- that the sample represents the diverse demographics of the population
- that the data collection methods were reliable and valid (that respondents provide honest and accurate information)
- that dietary patterns observed at the time of the survey were not likely to change due to seasonal variation in eating patterns and were representative of usual intake.

EFSA intake data were based on food consumption surveys from Finland, France, Germany, Ireland, Italy, Latvia, the Netherlands and Sweden with data collected between 2000 and 2012 (Turck et al. 2023). Intake estimates from these surveys were based on food only and did not include supplement use. As EFSA intake estimates came from multiple surveys, minimum and maximum values were reported for mean and 95th percentile, rather than a single value for each.

Australia

There is a lack of recent national data on selenium intake in Australia.

The most recent source of Australian national data on selenium intake is the 2011-2012 Australian Health Survey (ABS 2011) and the 2013 National Aboriginal and Torres Strait Islander Nutrition and Physical Activity Survey (ABS 2015). At the time of writing, selenium intake data from the 2023 National Nutrition and Physical Activity Survey had not yet been released.

Mean intake of selenium for the total Australian population ranged from 47 µg/day in the 2- to 3-year age group, to 94 µg/day in the 19- to 30-year age group. For Aboriginal and Torres Strait Islander Australians, the range was between 50 µg/day (2-3 years) and 93 µg/day (19-30 years), and

for non-Indigenous Australians, between 46 µg/day (2-3 years) and 98 (19-30 years) (see Table 3) (ABS 2011, 2015).

Overall, almost all Australians met their requirements for selenium intake (only 3% of males and 6% of females aged two years and over did not). Amongst those 71 years and over, approximately one in ten had inadequate selenium intakes (12% of males and 10% of females). Less than 5% of the population exceeded the UL for selenium (ABS 2011). Separate results were not reported for Aboriginal and Torres Strait Islander populations.

New Zealand

There is a lack of recent data on selenium intake for New Zealand.

According to the 2008-2009 New Zealand Adults Nutrition Survey (University of Otago & Ministry of Health 2011) and 2002 New Zealand National Children's Nutrition Survey (Ministry of Health 2003), the median usual daily selenium intake from food for the total New Zealand population was 67 µg for males and 47 µg for females. Older males and females aged 71+ years (52 µg and 40 µg, respectively) and females aged 15–18 years (39 µg) had lower median intakes of selenium than 31–50-year-old males and females (78 µg and 52 µg, respectively).

Mean selenium intake for the total New Zealand population ranged from 28 µg/day in the 5- to 6-year age group and 67 µg/day in the 31- to 50-year age group. For the Māori population, the range was 34 µg/day (5-6 years) to 69 µg/day (19-30 years); for the Pacific population, 32 µg/day (5-6 years) to 85 µg/day (31-50 years); and for the 'European and other' population, 26 µg/day (5-6 years) to 65 µg/day (31-50 years). For more detail, see Table 3 (Ministry of Health 2003; University of Otago & Ministry of Health 2011).

Overall, although selenium intakes in the New Zealand population aged 15 and over had increased since the previous survey in 1997, intakes were still inadequate for around one-third of males (32%) and over half (58%) of females. Females aged 15–18 years had a consistently high prevalence of inadequate intake (over 70%) across all ethnic groups (University of Otago & Ministry of Health 2011). Results from the 2002 New Zealand National Children's Nutrition Survey suggested that overall, New Zealand children (aged 5 to 14 years) were at risk of having inadequate selenium intakes, especially older children (11-14 years). No estimates of the proportion of the population exceeding the UL for selenium were reported (Ministry of Health 2003).

Table 4. Selenium intake comparison — mean intake (µg/day)

Population	Age Group (years)								
	CHILDREN AND ADOLESCENTS					ADULTS			
Australia *(food and supplements)*	**2-3yrs**	**4-8yrs**		**9-13yrs**	**14-18yrs**	**19-30yrs**	**31-50yrs**	**51-70yrs**	**71+yrs**
TOTAL	49, 45 *(47)*	61, 55 *(58)*		80, 69 *(75)*	96, 73 *(85)*	110, 77 *(94)*	105, 79 *(92)*	97, 80 *(89)*	85, 72 *(79)*
Aboriginal and Torres Strait Islander	51, 48 *(50)*	66, 60 *(63)*		83, 72 *(78)*	93, 72 *(83)*	111, 75 *(93)*	105, 75 *(89)*	86, 70 *(77)*	-
non-Indigenous	47, 45 *(46)*	63, 55 *(59)*		78, 66 *(72)*	93, 70 *(82)*	119, *77 (98)*	105, 81 *(93)*	93, 79 *(86)*	-
New Zealand *(food only)*	**<5**	**5-6yrs**	**7-10yrs**	**11-14yrs**	**15-18yrs**	**19-30yrs**	**31-50yrs**	**51-70yrs**	**71+yrs**
TOTAL	-	31, 26 *(28)*	37, 33 *(35)*	49, 36 *(43)*	67, 41 *(54)*	68, 47 *(57)*	79, 54 *(67)*	64, 52 *(58)*	57, 42 *(49)*
Māori	-	35, 32 *(34)*	38, 35 *(37)*	52, 39 *(46)*	66, 42 *(54)*	80, 58 *(69)*	87, 50 *(68)*	81, 55 *(68)*	-
Pacific	-	34, 30 *(32)*	45, 36 *(41)*	56, 40 *(48)*	66, 38 *(52)*	83, 53 *(68)*	104, 65 *(85)*	79, 57 *(68)*	-
NZEO	-	28, 23 *(26)*	36, 32 *(34)*	48, 33 *(40)*	- - *(52)*	- - *(52)*	- - *(65)*	- - *(54)*	-
European Member States *(food only)*	**1-3yrs**	**3-10yrs**		**10-18yrs**		**18-64yrs**		**65-74yrs**	**75+yrs**
(Max mean)	- - *(36)*	- - *(44)*		- - *(54)*		- - *(58)*		- - *(55)*	- - *(56)*
(Min mean)	- - *(18)*	- - *(22)*		- - *(38)*		- - *(39)*		- - *(38)*	- - *(35)*

Abbreviations: Max, maximum; Min, minimum; NZEO, New Zealand European and Other; yrs, years.
- data unavailable
male value, female value (*mean of male and female values)*

Table 5. Selenium intake comparison — 90th/95th percentile intake (µg/day)*

Population	Age Group (years)								
	CHILDREN AND ADOLESCENTS					ADULTS			
Australia (P95) *(food and supplements)*	**2-3yrs**	**4-8yrs**		**9-13yrs**	**14-18yrs**	**19-30yrs**	**31-50yrs**	**51-70yrs**	**71+yrs**
TOTAL	65, 59 *(62)*	80, 72 *(76)*		118, 103 *(111)*	140, 109 *(125)*	160, 114 *(137)*	153, 117 *(135)*	143, 118 *(131)*	125, 107 *(116)*
New Zealand (P90)* *(food only)*	**<5**	**5-6yrs**	**7-10yrs**	**11-14yrs**	**15-18yrs**	**19-30yrs**	**31-50yrs**	**51-70yrs**	**71+yrs**
TOTAL	-	42, 34 *(38)*	54, 51 *(53)*	81, 46 *(63)*	91, 59 *(75)*	85, 58 *(71)*	102, 74 *(88)*	87, 82 *(85)*	87, 58 *(73)*
Māori	-	56, 52 *(54)*	59, 53 *(56)*	86, 60 *(73)*	99, 70 *(85)*	120, 93 *(107)*	145, 66 *(105)*	118, 87 *(103)*	-
Pacific	-	52, 41 *(47)*	69, 52 *(61)*	94, 59 *(77)*	90, 59 *(75)*	146, 79 *(113)*	194‡, 110 *(152)*	147, 91 *(119)*	-
NZEO	-	39, 34 *(37)*	51, 45 *(48)*	75, 47 *(48)*	- - *(73)*	- - *(76)*	- - *(91)*	- - *(81)*	-
European Member States *(food only)*	**1-3yrs**	**3-10yrs**		**10-18yrs**		**18-64yrs**		**65-74yrs**	**75+yrs**
(Max P95)	- - *(59)*	- - *(68)*		- - *(92)*		- - *(99)*		- - *(97)*	- - *(57**)*
(Min P95)	- - *(30)*	- - *(33)*		- - *(61)*		- - *(71)*		- - *(71)*	- - *(57**)*

Abbreviations: Max, maximum; Min, minimum; NZEO, New Zealand European and Other; P90, 90th percentile; P95, 95th percentile; yrs, years.
*New Zealand reported 90th percentile, while Australia and EFSA reported 95th percentile values
**95th percentile only reported for one survey, therefore the minimum and maximum P95 are the same value
- *data unavailable*
male value, female value (*mean of male and female values)*
‡ Highest value overall
.

Comparison of Australian and New Zealand intake estimates with EFSA

Adults

For Australia, the age group with the highest mean and 95th percentile values was the 19–30-year age group for all populations. For New Zealand the highest mean and 90th percentile values were for the 31–50-year age group for all populations except the Māori population, who had its highest intake in the 19–30-year age group (see Table 3 and Table 4). The populations with the highest intake overall was New Zealand 31–50-year-old Pacific males, with a 90th percentile intake of (194 µg/day, food only), followed by Australian 19–30-year-old males, with a 95th percentile intake of 160 µg/day (food and supplements) (see Table 4).

Overall, when comparing mean and 90th or 95th percentile intake estimates from Australia and New Zealand to those reported by EFSA, New Zealand intake levels appear to be generally consistent with those in Europe, while Australian intake levels appear higher. In the New Zealand 19–30-year and 31–50-year age groups, values are close to or above EFSA's maximum values. However, direct comparison between these populations is difficult due to differences in age grouping (31–50 years vs 18–64 years) and the use of 90th and 95th percentiles across populations and Australian intake data including food and supplement intake, while EFSA and NZ include food only.

Children and adolescents

Overall, for all children and adolescent age groups, selenium intake estimates were higher for Australia when compared with EFSA (Australian 95th percentile was higher than EFSAs maximum 95th percentile estimate for all age groups). New Zealand's 90th percentile values generally fell between EFSAs minimum and maximum 95th percentile estimates. However, it should be noted that it is difficult to make direct comparisons between Australian, New Zealand and EFSA estimates due to the differences in reporting age groups and the use of 95th percentile estimates by Australia and EFSA, and 90th percentile estimates used by New Zealand (see Table 4).

Limitations of selenium intake estimates and comparisons

When comparing intake estimates between Australia, New Zealand and EFSA, it should also be noted that intake values are derived from different surveys, different food composition tables and databases, and in different years. Furthermore, when comparing Australian intake estimates with those presented by EFSA, it should be noted that the Australian dietary intake data included food and supplements, while New Zealand and EFSA presented intakes from food only.

Comparison between population groups across jurisdictions can be difficult, as age groups do not always align and estimates are not reported for some populations (i.e. intake values for children <5 years in New Zealand, and 95th percentile values for Aboriginal and Torres Strait Islander populations). There are also inconsistencies in data reported for higher levels of intake with 95th percentile values provided for EFSA and Australia, and 90th percentile values for New Zealand.

There are further uncertainties in estimating selenium intake due to the significant variability in selenium content in foods, which is influenced by the geochemistry and selenium content of the soil (Tinggi 2003). The origin of the foods analysed can greatly affect their selenium content, leading to potential inaccuracies in food composition tables if the analytical data do not adequately capture this variability or if borrowed values are used these intake estimates should therefore be interpreted with caution (Turck et al. 2023).

Selenium status

There is no national or government data around the selenium status of the Australian or New Zealand population, consequently research studies have instead been used to attain this data. Only studies that used plasma or serum selenium levels to measure selenium status were included for consistency (see Table 5 and Table 6). Data for a range of studies are presented for completeness. However, it should be noted that these studies generally involved small sample sizes, and were conducted in various populations across different regions and over differing time periods, and using varied methodologies. Consequently, differences in reported selenium status may reflect temporal, geographic, or sampling differences between studies, or other unknown factors. Consequently, direct comparisons between studies have been avoided.

Australia

Overall, data in Table 5 suggests that Australian adults are not at significant risk of selenium deficiency, with mean plasma selenium level exceeding the 100 µg/L threshold for maximisation of GPx activity. Some studies in younger women or Northern Tasmanian populations reported mean plasma selenium levels below this threshold, which may suggest an increased risk of deficiency in these populations. One study conducted in older adults living in Victoria found notably high selenium levels, with a mean of 169.3 ± 60.4 µg/L (Cardoso et al. 2018). The authors proposed that this higher level was likely due to dietary habits.

Table 6. Plasma/serum selenium status of various population groups in Australia (µg/L)

Population group	Region	Sample size (n)	Mean serum/plasma Se concentration ± SD (µg/L)	Study
General Population				
Adults	Australia	140	100.2 ± 1.3	Lymbury et al. (2008)
Adults	South Australia	288	103	Lyons et al. (2004)
Adult Men (18-49 years)	Southern Tasmania	335	112.6	Jacobson et al. (2007)
Adult Men (50-65 years)	Southern Tasmania		110.9	Jacobson et al. (2007)
Adult Women (18-49 years)	Southern Tasmania		103.8	Jacobson et al. (2007)
Adult Women (50-65 years)	Southern Tasmania		112.0	Jacobson et al. (2007)
Adults	Northern Tasmania	498	89.1	Beckett and Ball (2011)
Specific Populations				
Older Adults (mean age 70.7 years)	Victoria	154	169.3 ± 60.4	Cardoso et al. (2018)
Female University Students	Sydney	289	87.7 ± 16.9# (1.11 ± 0.21 µmol/L)	Fayet-Moore et al. (2014)
Pregnant Women	Adelaide	1065	72.6 ± 11.90# (0.919 ± 0.151 µmol/L)	Wilson et al. (2018)
Pregnant Women (multiple micronutrient supplement)	Southeast Queensland	84	75.5	McAlpine et al. (2019)
Pregnant Women (no supplement)	Southeast Queensland	43	74.1	McAlpine et al. (2019)
Newborn infants (preterm)	Adelaide	90	29 ± 14	Daniels et al. (2000)
Newborn infants (term)	Adelaide	48	33 ± 11	Daniels et al. (2000)

 # mean and standard deviation (SD) reported in µmol/L were converted to µg/L using the selenium atomic mass (78.96).

Table 7. Plasma/serum selenium status of various population groups in New Zealand (µg/L)

Population group	Region	Sample size (n)	Mean serum/plasma Se concentration ± SD (µg/L)	Study
General Population				
Adults	New Zealand	52	66.3 ± 11.1 (0.84 ± 0.14 µmol/L)	Duffield et al. (1999)
Adults	New Zealand	449	81.3 ± 18.9# (1.03 ± 0.24 µmol/L)	McLachlan (2003)
Specific Populations				
Breastfed Infants (6-12 months)	South Island, New Zealand	22	54.5 ± 21# (0.69 ± 0.27 µmol/L)	McLachlan et al. (2004)
Non-breast-fed Toddlers (12-24 months)	South Island, New Zealand	91	45.0 ± 13.4# (0.57 ± 0.17 µmol/L)	McLachlan et al. (2004)
Toddlers (12 months)	New Zealand	51	64.0 ± 13.4# (0.81 ± 0.17 µmol/L)	Daniels et al. (2023)
Children (5-14 years)	New Zealand	1547	75.8# (0.96 µmol/L)	Thomson et al. (2007)
Māori Children (5-14 years)	New Zealand	444	75.8# (0.96 µmol/L)	Thomson et al. (2007)
Pasifika Children (5-14 years)	New Zealand	652	81.3# (1.03 µmol/L)	Thomson et al. (2007)
New Zealand European Children (5-14 years)	New Zealand	451	75.0# (0.95 µmol/L)	Thomson et al. (2007)
Pregnant Women (including those who are also breastfeeding)	South Island, New Zealand	30	58.4 ± 11.8# (0.74 ± 0.15 µmol/L)	McLachlan et al. (2004)
Breastfeeding Women	South Island, New Zealand	74	74.2 ± 12.6# (0.94 ± 0.16 µmol/L)	McLachlan et al. (2004)
Breastfeeding Women (3 months postpartum)	New Zealand	25	92.8 ± 3.7	Jin et al. (2020)
Breastfeeding Women (6 months postpartum)	New Zealand	24	106.0 ± 3.5	Jin et al. (2020)
Breastfeeding Women (12 months postpartum)	New Zealand	25	123.7 ± 14.5	Jin et al. (2020)
Older Women (mean age 74.9 years)	Dunedin, New Zealand	103	71.1 ± 19.7# (0.90 ±0.25 µmol/L)	De Jong et al. (2001)

 # mean and standard deviation (SD) reported in µmol/L were converted to µg/L using the selenium atomic mass (78.96).

New Zealand

The selenium status of the general population in New Zealand has historically been lower compared to other countries, primarily due to the low selenium content in New Zealand soils (Thomson et al. 2007). Although limited data are available, studies in adults suggest that selenium levels remain below the internationally accepted minimum level for the maximisation of GPx activity in plasma (100 µg/L; Table 6). This suggests that there may be an increased risk of selenium deficiency among the New Zealand population.

Thomson et al. (2007) found a higher selenium status of Pacific (Samoan, Tongan, Cook Island Mäori, Niuean, Tokelauan, Fijian) children than of Māori and NZEO (New Zealand European and Other) children. This is likely due to a combination of dietary factors and geographic differences in food supply owing to the importation of Australian wheat in the upper North Island, which is where most Pacific children live.

Key health outcomes of relevance for Australia and New Zealand

Excessive selenium consumption can lead to significant health issues, as discussed earlier in this report. Chronic high selenium intake can lead to persistent health problems like alopecia, fatigue, and neurological issues (Lippman et al. 2009). Acute selenium poisoning can cause symptoms such as nausea, vomiting, diarrhoea, hair loss, brittle nails, skin rashes, fatigue, and irritability (Alexander & Olsen 2023). In severe cases, it can result in neurological damage, respiratory distress, and cardiocirculatory failure however these cases are rare, with Gasmi et al. (1997) citing only 18 documented cases globally before 1997, half of them fatal, generally as a result of cardiocirculatory failure and or pulmonary oedema. The largest case of selenium toxicity in the United States of America was due to the misformulation of a dietary supplement that contained 200 times the labelled concentration of selenium. The outbreak affected 201 people, with frequently reported symptoms including diarrhoea, fatigue, hair loss, joint pain, nail discolouration or brittleness, and nausea; 1 person was hospitalised (MacFarquhar et al. 2010; Morris & Crane 2013). In Australia, the only reported case of accidental death due to the ingestion of a sodium selenite dose that was 10,000 times the recommended daily intake (See et al. 2006).

In Australia and New Zealand, the risk of selenium toxicity is relatively low due to the moderate selenium levels in the soil and food supply (Lymbury et al. 2008). While certain regions in Australia, such as central Queensland, have selenium-rich soils, the overall dietary selenium intake remains within safe limits for most of the population (Judson & Reuter 1999; Reilly 1996). In New Zealand, despite generally low soil selenium levels, it has been suggested that selenium status has improved

through the importation of selenium-rich foods from Australia and other sources (Thomson 2004; Thomson et al. 2007). This balanced selenium intake helps mitigate the risk of both deficiency and toxicity, ensuring that the general population in Australia and New Zealand maintains adequate selenium levels without exceeding safe limits.

It's also important to note that there is limited evidence on the rates of chronic selenosis causing alopecia in Australia and New Zealand with the Lippman et al. (2009) study being conducted in United States, Canada and Puerto Rico. Part of the challenge in assessing high selenium exposure is that there is some evidence to suggest populations can adapt to or tolerate high selenium intakes without showing major clinical symptoms (Fordyce 2012; World Health Organization 1996). This lack of data makes it challenging to fully understand the prevalence and impact of chronic selenium toxicity in these regions. Globally, soil selenium levels are highly variable and this is also the case within Australia (Fordyce 2012).

Summary of Evidence

Intake, status and health relationships

Alopecia

The SELECT study (involving over 8,700 healthy men per arm, aged 50 and above), investigated the effects of selenium supplementation (200 µg/day) in addition to a background diet (130 µg/day) over a median of 5.5 years (Lippman et al. 2009). The study found that selenium intake increased serum selenium levels significantly, compared to the placebo group. The primary endpoint was prostate cancer incidence, with secondary endpoints including other cancers, deaths, and cardiovascular events. Notably, the study reported a significantly increased risk of alopecia and other adverse events such as dermatitis (grade 1-2), halitosis, fatigue, and nausea in the selenium group. Strengths of the SELECT study were its large sample size (around 8,700 individuals per arm), its controlled setting regarding selenium intake (fixed supplemental dose), the high level of compliance, and its long duration. Furthermore, although alopecia was a self-reported outcome - with an attendant risk of bias - the set of selenosis symptoms were developed *a priori*, and symptoms were monitored using standardised criteria.

The EFSA panel concluded that no other studies published after Yang et al. (1989), which explored selenium toxicity at exposures below 850 µg/day, provided sufficient data to establish a No Adverse Effects Level (NOAEL). The findings from the SELECT study (Lippman et al. 2009) suggest that selenium intakes of around 330 µg/day compared to 130 µg/day can lead to toxicity, challenging the previously identified NOAEL of 850 µg/day. The EFSA panel highlighted that these results indicate the need to reassess the UL for selenium intake, identifying a Lowest Observed Adverse Effect Level (LOAEL) of 330 µg/day. This study was chosen for its robust design and large sample size, providing strong evidence of selenium toxicity at higher intake levels, this finding was not corroborated by smaller RCTs with similar or higher selenium intakes (Algotar et al. 2013; Thompson et al. 2016; Winther et al. 2015). However, it was noted that these RCTs had much smaller sample sizes and no or minimal recording on how the reported signs and symptoms were characterised and monitored.

Other health outcomes

When reviewing the literature to update selenium ULs for Europe, EFSA (2023) concluded that the available evidence did not support a positive relationship between dietary selenium intake and the risk of all-cause mortality, hypertension, type-2 diabetes, Alzheimer dementia, amyotrophic lateral sclerosis, impaired functional neuropsychological development in children, or thyroid diseases.

Research on the association between selenium and the risk of chronic diseases such as cancer or type 2 diabetes has not shown a clear causal link.

Risk of cancer

The Nutritional Prevention of Cancer Trial (Clark et al. 1996; Duffield-Lillico et al. 2003) concluded that taking 200 µg/day of selenium supplements increased the risk of squamous cell carcinoma and total non-melanoma skin cancer in individuals at high risk for these conditions. However, the study authors suggested that exposure to arsenic-containing pesticides could be a confounding factor. The study also investigated the effects of selenium on other cancer types and found reduced incidences of lung cancer, colorectal cancer, and prostate cancer, especially in men with low baseline selenium levels (Clark et al. 1996; Duffield-Lillico et al. 2003).

More recently, Vinceti et al. (2018) published Cochrane review, evaluating the protective effect of selenium intake on cancer risk. The review included 10 RCTs and 70 observational studies, and the findings showed no reduction in the risk of overall cancer or specific cancers. Some RCTs reviewed reported a higher incidence of high-grade prostate cancer and type 2 diabetes in participants taking selenium. However, these studies did not find clear evidence that baseline selenium status influenced these outcomes. The EFSA panel found that the available body of evidence did not suggest a positive relationship between dietary selenium exposure and risk of skin and prostate cancer (Turck et al. 2023).

Type 2 diabetes

Research on the relationship between selenium and type 2 diabetes has shown inconsistencies. Early studies in mice indicated potential benefits of selenium in diabetes management (McNeill et al. 1991; Mueller & Pallauf 2006). However, more recent human studies, including two United States of America RCTs with cancer as the primary endpoint (Nutritional Prevention of Cancer (NPC) and SELECT) revealed mixed results (Lippman et al. 2009; Stranges et al. 2007). The NPC study found an increased risk of type 2 diabetes with selenium supplementation, particularly in men and those with higher baseline serum selenium levels. Conversely, the SELECT study did not find an increased risk in the supplemented group. Other RCTs also showed no consistent association between selenium supplementation and type 2 diabetes, except in older participants (Thompson et al. 2016).

Vinceti et al. (2018) Cochrane review found that all RCTs reviewed that included diabetes as an endpoint showed an increased incidence of type 2 diabetes among selenium-allocated participants. This finding is further supported by results from observational human studies included in the review. The relationship appears nonlinear, with increased risk at higher selenium intake levels above 80 µg/day. Compared to plasma and serum concentrations of 90 µg/L, a value of 160 µg/L produced a

risk ratio of 1.96 for type 2 diabetes. Mechanisms suggested the overexpression of GPx1 or compromised insulin signalling leading to hyperinsulinemia and glycaemia (Steinbrenner et al. 2022). The Nordic Nutrition Recommendations concluded that the evidence is not consistent enough to establish a causal relationship or to set dietary reference values for selenium based on diabetes risk (Alexander & Olsen 2023). The 2023 EFSA report reviewed similar studies to the Nordic Nutrition Recommendations (Algotar et al. 2013; Lippman et al. 2009; Stranges et al. 2007; Thompson et al. 2016) and concluded that there is moderate certainty of a positive and causal relationship between selenium intake and the risk of type 2 diabetes based on RCTs. However, the available evidence from observational studies and information about the mode of action cannot be used to alter the level of certainty in this conclusion.

Derivation of draft NRVs

Nutritional adequacy recommendations

Nutritional adequacy recommendations were not within scope for this review. Consequently, the EAR and RDI recommendations for selenium - and the evidence underpinning them - remain unchanged. However, during this update, EAR and RDI recommendations for alternative age groupings for children and adolescents were derived, to align with different educational and developmental stages. These additional age groupings will facilitate reporting against national survey data.

Weighted EARs were derived for each of the additional age groups using the formula:

$$EAR\ New\ age = \frac{(EAR_{2006\ Age\ Group\ 1} \times Years\ of\ Overlap) + (EAR_{2006\ Age\ Group\ 2} \times Years\ of\ Overlap)}{Total\ No. Years\ in\ New\ Age\ Group}$$

For example, to calculate the EAR for children aged 5 to under 12 years (a 7 year age grouping), a weighted average calculation would use the EAR for the following age groups:

- 4 to under 9 years age group (4 years out of the total 7 year span fall within this group)
- 9 to under 14 years age group (3 years out of the total 7 year span fall within this group)

$$EAR_{\ 5\ to\ under\ 12\ years} = \frac{(\mathrm{EAR}_{4\ to\ under\ 9\ years} \times 4) + (EAR_{9\ to\ under\ 13\ years} \times 3)}{7}$$

Calculated EARs were then rounded and the RDI calculated using a coefficient of variation (CV) of 10%. Table 8 shows the calculated and rounded EAR and RDIs derived for new 'additional age groups'.

Table 8. EAR and RDI calculations for additional age groups

Age	$EAR_{calculated}$ (µg/day)	$EAR_{Rounded}$ (µg/day)	$RDI_{Calculated}$ (µg/day)	$RDI_{Rounded}$ (µg/day)
12 to under 24 months	N/A	20	N/A	25
2 to under 5 years	21.7	20	24	25
5 to under 12 years	31.4	30	36	40
Males 12 to under 18 years	53.3	55	66	65
Females 12 to under 18 years	46.7	45	54	55

Further information about age groupings and associated reference weights used in calculations is presented in the Methodological Framework for the Review of Nutrient Reference Values (NHMRC 2025).

Upper level (UL)

Updating the NHMRC selenium UL involved adapting EFSAs 2023 selenium UL (EFSA 2023) to the Australia New Zealand context through a GRADE Evidence-to-Decision process (see 'Rationale for prioritising this update'). The process involved guidance from the Steering Group Advisory Committee (NRV derivation methodological experts and selenium nutrition experts) and was based on methods outlined in the revised NHMRC Methodological Framework for the Review of Nutrient Reference Values (NHMRC 2025b). The NHMRC Steering Group Advisory Committee assessed the updated EFSA selenium UL against administrative and technical criteria and found it suitable for adopting or adapting to the Australian and New Zealand context (Appendix A).

Adults

EFSA methods for deriving UL

The EFSA UL for adults was based on a single, large RCT (roughly 8,700 per arm) exploring the relationship between selenium supplementation (200 µg/day) vs placebo on alopecia (Lippman et al. 2009). EFSA selected a LOAEL of 330 µg/day as the reference point for the revised selenium UL, based on an increased risk of alopecia with selenium with intakes of 330 µg/day, compared with lower (unsupplemented) intakes. Alopecia was considered a suitable critical end point, as it is a well-established, reversible, early observable effect of excess selenium intake.

EFSA noted that although the population of the SELECT study were men aged 50-years and over, there was no evidence that younger men might be more sensitive to selenium toxicity, so the LOAEL of 330 µg/day was considered applicable to the entire adult male population.

An uncertainty factor of 1.3 was applied by EFSA, to account for the following uncertainties:

- The use of a LOAEL rather than a NOAEL as the reference point (noting that study results indicated that the NOAEL might be close to the LOAEL),
- The lack of data in women (whilst noting that there is no evidence to suggest that sensitivity to excess selenium varies by sex).

This was noted to be a pragmatic UF based on expert-judgement.

The result was rounded to the nearest 5 µg/day to establish a UL of 255 µg/day for adult men and women (including pregnant and lactating women; no evidence was found of increased sensitivity for these populations).

Adaptation to the Australian and New Zealand context

For the Australian and New Zealand context, a UF of 1 was applied to the reference point (LOAEL of 330 µg/day), to establish a UL of 330 µg/day for adults. The UF of 1 was a pragmatic decision based on the judgement of Australian and New Zealand experts. This UF was selected to reflect:

- the mild and reversible nature of the end point (alopecia)
- the more robust evidence base for revised UL recommendations (compared to the evidence underpinning the 2006 UL)
- the likelihood that the LOAEL is close to the NOAEL and a lack of evidence to suggest adverse effects with selenium intakes below the revised UL.

On a practical level, consideration was also given to ensuring an adequate buffer between the proposed UL and the EAR and RDI, and usual population intakes in Australia and New Zealand. A UL of 330 µg/day better aligns with most recent evidence without lowering it to a level at which the proportion of the population which exceeds the UL without demonstrating symptoms increases significantly.

Pregnancy and lactation

The 2023 EFSA review did not identify any evidence to suggest an increased sensitivity to selenium during pregnancy or lactation. Therefore, the ULs derived for adults and adolescents also applies during pregnancy and lactation. This is consistent with EFSAs selenium ULs, which apply to both the general population and women who are pregnant or lactating and is also consistent with the NHMRC 2006 ULs.

Currently, selenium intake recommendations (EAR – Estimated Average Requirement and RDI – Recommended Dietary Intake) are higher during pregnancy and lactation (NHMRC 2006).

Children and adolescents

As there was no data to support the derivation ULs for children and there is no evidence to indicate that children may be more susceptible to selenium toxicity than adults, the adapted EFSA selenium ULs for adults were extrapolated to children using allometric scaling. This is consistent with EFSA's approach to deriving ULs for children and adolescents.

Allometric scaling using reference bodyweights was used to derive a UL for each age group for children and adolescents using the following equation:

$$UL_{child} = UL_{adult}\left(\frac{Weight_{child}}{Weight_{adult}}\right)^{0.75}$$

Where:

UL adult = 330 µg/day

$Weight_{adult}$ = 62.9 kg

For standard age groupings, the inputs and calculated UL values are shown in Table 9, with inputs and calculated UL values for alternative age groups presented in Table 10.

Table 9. UL calculations for standard age groupings — children and adolescents (extrapolation from adult values)

Age	Weight Child (kg)	Calculated UL Child (µg/day)	Rounding	UL Child (µg/day)
1 to under 4 years	13.0	101.2	-1.2	100
4 to under 9 years	22.4	152.1	-2.1	150
9 to under 14 years	40.7	238.1	-3.1	235
14 to under 18 years	57.6	308.9	-3.9	305

Table 10. UL calculations for alternative age groupings — children and adolescents (extrapolation from adult values)

Age	Weight Child (kg)	Calculated UL Child (µg/day)	Rounding	UL Child (µg/day)
12 to under 24 months	10.6	86.8	-1.8	85
2 to under 5 years	15.9	117.6	2.4	120
5 to under 12 years	28.6	182.7	2.3	185
12 to under 18 years	54.5	296.4	-1.4	295

Further information about age groupings, reference weights and scaling methods used is presented in the Methodological Framework for the Review of Nutrient Reference Values (NHMRC 2025b).

Benchmarking

International comparisons

Table 11 shows NRV recommendations for selenium UL across comparable international jurisdictions. Tabler 12 shows NRV recommendations for selenium UL for alternative age groupings. To account for differing age groupings across jurisdictions, values have been adjusted using a weighted average calculation [2]. Adjusted values are denoted by * in the table.

Additional benchmarking against comparable international jurisdictions is not possible for children and adolescents, as no children's ULs were available from the UK Expert Group on Vitamins and Minerals (EVM) or the World Health Organization/Food and Agriculture Organization of the United Nations (WHO/FAO). The international data for comparison for children and adolescents were the USA IOM values (which the 2006 NHMRC values were adopted from) and the 2000 SCF European values, that are superseded by the EFSA 2023 values.

Table 11. Comparison of proposed ULs with ULs from comparable international jurisdictions

Age	NHMRC (2025) Proposed UL (µg/day)	NHMRC (2006) Current UL (µg/day)	Europe EFSA (2023) UL (µg/day)	Europe SCF (2000) UL (µg/day)	US IOM (2000) UL (µg/day	UK EVM (2003) UL (µg/day)	WHO/ FAO (2004) UL (µg/day)
Adults 18 +years	330#	400#	255#	300#	400#	450^	400^
0 – 6 months	45	45	45*		-	-	-
7 – 12 months	60	60	60*		-	-	-
1 to under 4 years	100	90	70		-	-	-
4 to under 9 years	150	150	110*		-	-	-
9 to under 14 years	235	280	185*		-	-	-
14 to under 18 years	305	400	220*		-	-	-

Abbreviations: EVM, UK Expert Group on Vitamins and Minerals (UK); IOM, Institute of Medicine (US); NHMRC, National Health and Medical Research Council; SCF, Scientific Committee on Food; WHO/FAO, World Health Organization/Food and Agriculture Organization of the United Nations; UL: upper level.

Including pregnant and lactating women.

^ no information provided on UL for pregnant or lactating women

*adjusted value to fit age groups

[2] For example, to calculate a weighted NRV for children aged 5 to under 12 years (a 7 year age grouping) based on the following age groups:

- 4 to under 9 years age group (4 of the 7 year span falls within this group)
- 9 to under 14 years age group (3 of the 7 year span falls within this group)

$$\text{Weighted NRV}_{\text{5 to under 12 years}} = \frac{(\text{NRV}_{\text{child 4 to under 9years}} \times 4) + (\text{NRV}_{\text{child 9 to under 13years}} \times 3)}{7}$$

Table 12. Comparison of alternative age groups proposed ULs with ULs from comparable international jurisdictions

Age	NHMRC (2025) Proposed UL (µg/day)	NHMRC (2006) Current UL (µg/day)	Europe EFSA (2023) UL (µg/day)	Europe SCF (2000) UL (µg/day)	US IOM (2000) UL (µg/day	UK EVM (2003) UL (µg/day)	WHO/ FAO (2004) UL (µg/day)
Adults 18 +years	330#	400#	255#	300#	400#	450^	400^
0 – 6 months	45	45	45*		-	-	-
7 – 12 months	60	60	60*		-	-	-
12 to under 24 months	85	105*	65*		-	-	-
2 to under 5 years	120	145*	90*		-	-	-
5 to under 12 years	185	220*	140*		-	-	-
12 to under 18 years	295	360*	230*		-	-	-

Abbreviations: EVM, UK Expert Group on Vitamins and Minerals (UK); IOM, Institute of Medicine (US); NHMRC, National Health and Medical Research Council; SCF, Scientific Committee on Food; WHO/FAO, World Health Organization/Food and Agriculture Organization of the United Nations; UL: upper level.

Including pregnant and lactating women.

^ no information provided on UL for pregnant or lactating women

*adjusted value to fit alternative age group

Food system and foundation diet modelling

Data from the food modelling system developed to inform revision to the Australian Dietary Guidelines (NHMRC 2011) were extracted for comparison with NRV recommendations. Extracted data are presented in Table 13 (adults), Table 14 (during pregnancy), Table 15 (during lactation), and Table 16 (children and adolescents). Estimates of dietary selenium intake among adults, including during pregnancy and lactation, *consistently falls below both current and proposed ULs,* which suggests that a reduction in the UL would be safe and feasible.

Adults

Table 13. Estimated selenium intake in adults from food modelling (µg/day) *(Source: Baghurst et al. 2011)*

Population	Core food groups	Aust. Guide to Healthy Eating	Foundation diets - overall	Omnivore	Rice-based	Pasta-based	Lacto-ovo-vegetarian
Persons 19+ years	39	-	-	-	-	-	-
Males 19 – 30 years	-	-	88	-	72	81	73
Males 31 – 50 years	-	-	91	-	74	83	75
Males 51 – 70 years	-	-	82	-	71	79	65
Males 70+ years	-	-	77	-	67	74	63
Females 19 – 30 years	-	-	75	-	80	92	58
Females 31 – 50 years	-	-	78	-	84	96	61
Females 51 – 70 years	-	-	73	-	58	62	54
Females 70+ years	-	-	65	-	54	55	48

Source: A modelling system to inform the revision of the Australian Guide to Healthy Eating (Baghurst et al. 2011)

Pregnancy

Table 14. Estimated selenium intake during pregnancy from food modelling (µg/day) *(Source: Baghurst et al. 2011)*

Population	Core food groups	Aust. Guide to Healthy Eating	Foundation diets - overall	Omnivore	Rice-based	Pasta-based	Lacto-ovo-vegetarian
Pregnant persons (age not specified)	-	-	-	-	-	-	-
Pregnant females 14 – 18 years	-	-	116	-	-	-	-
Pregnant females 19 – 30 years	-	-	110	-	-	-	-
Pregnant females 31 – 50 years	-	-	115	-	-	-	-

Source: A modelling system to inform the revision of the Australian Guide to Healthy Eating (Baghurst et al. 2011)

Lactation

Table 15. Estimated selenium intake during lactation from food modelling (µg/day) *(Source: Baghurst et al. 2011)*

Population	Core food groups	Aust. Guide to Healthy Eating	Foundation diets - overall	Omnivore	Rice-based	Pasta-based	Lacto-ovo-vegetarian
Lactating persons (age not specified)	-	-	-	-	-	-	-
Lactating females 14 – 18 years	-	-	93	-	-	-	-
Lactating females 19 – 30 years	-	-	90	-	-	-	-
Lactating females 31 – 50 years	-	-	95	-	-	-	-

Source: A modelling system to inform the revision of the Australian Guide to Healthy Eating (Baghurst et al. 2011)

Children and adolescents

Modelled selenium intake data demonstrate that average intakes across infant, child and adolescent populations meet nutritional requirements while remaining well below current and proposed UL values. As shown in Tables 16, most modelled values – based on Foundation Diet modelling – are at or below half of the lowest proposed UL (adapted EFSA UL). Despite potential underestimation due to selenium being modelled as an output rather than an input, and incomplete food composition data, the modelled intake patterns are consistent with empirical health data from both Australia and New Zealand (Tables 4 & 5). These findings support the feasibility of implementing a lower UL for children and adolescents without requiring changes to current dietary patterns.

Table 16. Estimated selenium intake in children and adolescents from food modelling (µg/day) *(Source: Baghurst et al. 2011)*

Population	Core food groups	Aust. Guide to Healthy Eating	Foundation diets - overall	Omnivore	Rice-based	Pasta-based	Lacto-ovo-vegetarian
Persons 4 – 7 years	-	-	-	-	-	-	-
Persons 8 – 11 years	-	-	-	-	-	-	-
Persons 12 – 18 years	-	-	-	-	-	-	-
Males 13 – 23 months	-	-	38	-	-	-	-
Males 2 – 3 years	-	-	41	-	-	-	-
Males 4 – 8 years	-	-	54	-	-	-	-
Males 9 – 11 years	-	-	68	-	-	-	-
Males 12 – 13 years	-	-	75	-	-	-	-
Males 14 – 18 years	-	-	78	-	-	-	-
Females 13 – 23 months	-	-	36	-	-	-	-
Females 2 – 3 years	-	-	39	-	-	-	-
Females 4 – 8 years	-	-	52	-	-	-	-
Females 9 – 11 years	-	-	67	-	-	-	-
Females 12 – 13 years	-	-	72	-	-	-	-
Females 14 – 18 years	-	-	82	-	-	-	-

Source: A modelling system to inform the revision of the Australian Guide to Healthy Eating (Baghurst et al. 2011)

Proposed Recommendations

Population	EAR (µg/day)	RDI (µg/day)	AI (µg/day)	UL (µg/day)	Comment
Infants					
0 to under 7 months			12	45	*Not updated*
7 to under 12 months			15	60	*Not updated*
Children and adolescents					
1 to under 4 years	20	25		100	
4 to under 9 years	25	30		150	
9 to under 14 years	40	50		235	
Males 14 to under 18 years	60	70		305	
Females 14 to under 18 years	50	60		305	
Adults					
Males 18 to under 30 years	60	70		330	
Males 30 to under 50 years	60	70		330	
Males 50 to under 65 years	60	70		330	
Males 65 to under 75 years	60	70		330	
Males 75 years and over	60	70		330	
Females 18 to under 30 years	50	60		330	
Females 30 to under 50 years	50	60		330	
Females 50 to under 65 years	50	60		330	
Females 65 to under 75 years	50	60		330	
Females 75 years and over	50	60		330	
Pregnancy					
Any age	55	65		330	
Lactation					
Any age	65	75		330	

Additional, alternative age groupings by school-level (for reporting against National Nutrition Survey results):

Age (years)	EAR (µg/day)	RDI (µg/day)	AI (µg/day)	UL (µg/day)
13 – 23 months	20	25		85
2 – 4 years	20	25		120
5 – 11 years	30	40		185
Males 12 – 17 years	55	65		295
Females 12 – 17 years	45	55		295

Comprehensive Evidence-to-Decision Frameworks documenting how the final recommendations have been determined are presented in Appendix B.

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Appendix A — Administrative and technical criteria for assessing existing nutrient reference values for adopting or adapting

Title/Reference: EFSA Panel on Nutrition, Novel Foods and Food Allergens (NDA), Turck D, Bohn T, Castenmiller J, de Henauw S, Hirsch-Ernst K-I, Knutsen HK et al. Scientific opinion on the tolerable upper intake level for selenium. EFSA Journal. 2023 Jan 20;21(1):e07704. doi: 10.2903/j.efsa.2023.7704

Assessment made by NHMRC Project Team: 12 February 2024

NHMRC's preference is to review sources that have made their processes publicly available, however it is understood that some technical aspects of an organisations' development process may need to be requested from the developer.

Overall guidance/advice development process

Criteria	Yes/No/ NA	Comment	Page #
Are the administrative processes (e.g. the NRV development process and associated governance, principles and procedures) documented and publicly available?	Yes	Yes – they've outlined their methodologies associated with assessment in detail.	
Are the key stages of the organisation's NRV development processes compatible with NHMRC processes? (i.e., relevant and useful, transparent, overseen by a guideline development group/committee, COI management, focussed on health-related outcomes, evidence informed, actionable recs, up to date and accessible)	Yes	It is broadly compatible with NHMRC 2016 Standards: Relevant and useful, transparent, overseen by a GDG, COI management, focussed on health related outcomes, evidence informed, actionable recs, up to date and accessible.	
Was the work overseen by an expert advisory committee?	Yes	European Food Safety Authority NDA Panel – Panel members are listed	2
Are potential conflicts of interest of committee members declared, managed and/or reported?	Yes	Open EFSA (europa.eu). Management policies for COI are found Here.	2

Criteria	Yes/No/ NA	Comment	Page #
Are funding sources declared?	Yes	It is noted that this report was requested by the European Commission. EFSA, as an agency of the European Union, is strictly funded by public funds, almost entirely from the EU budget. Budget is published annually here: Statement of revenue and expenditure for the 2023 financial year	
Was there public consultation on this work? if yes, is the public consultation documented and/or published?	Yes	Yes – 14 Sept 22 – 19 Oct 22 Outcomes published in Annex F	16
Was the guidance/advice developed or updated recently?	Yes	2022 – Adopted 2023	

Evidence review parameters

Criteria	Yes/No/ NA	Comment	Page #
Are decisions about scope, definitions and evidence review parameters documented and publicly available?	Yes	Terms of reference and interpretation is stated. Problem is identified and clinical questions including method of how they want to source the evidence	8
Were clinical/research questions articulated and PICO criteria outlined appropriate to the topic?	Yes	8 questions were articulated. sQ8 is a reference to data in the EU and needs to be adapted for Australian/NZ data.	8
Does the organisation use or adopt review findings or risk assessments from other organisations?	No		
• what process was used to critically assess these external findings?	n/a		
Did the organisation undertake their own systematic literature review?	Yes	EFSA undertook reviews as outlined in a research protocol with the assistance	
Has the evidence report been reviewed by experts independent from the review authors? (e.g. peer review or committee review)?	Yes	EFSA have contracted some reviews and the expert committee have assessed reviews independently.	
Does the organisation use or undertake systematic literature review methods to identify and select data underpinning the advice?	Yes	A Protocol was established and published before commencement.	
• are the methods used documented clearly?	Yes		

Criteria	Yes/No/ NA	Comment	Page #
• are inclusion/exclusion criteria used to select or exclude certain studies from the review?	Yes	Eligible designs, populations and measurements are listed. A PRISMA flowchart is provided. Further details are provided in Annex A.	9
• is justification of inclusion/exclusion criteria provided?	Yes	A rationale is provided at Annex E.	

Evidence search

Criteria	Yes/No/ NA	Comment	Page #
Are databases and other sources of evidence specified?	Yes	PubMed, Embase and Cochrane Library	9
Does the literature search cover at least more than one scientific database as well as additional sources (which may include government reports and grey literature)?	Yes	References international reports used as well as scientific literature. Grey literature was not searched.	
Is the date range of the literature search specified and justified?	Yes	7 May 2021 for Q1 and 3 May 2021 for Q2 with no limit on inception date.	
Are search terms and/or search strings specified?	Yes	Outlined in the protocol at Annex A on the website.	

Critical appraisal methods and tools

Criteria	Yes/No/ NA	Comment	Page #
Is risk of bias of individual studies assessed and taken into consideration?	Yes	The appraisal was performed using the Office of Health Assessment and Translation (OHAT) RoB tool developed by the US National Toxicology Program (NTP) (OHAT-NTP, 2015). The RoB criteria and rating instructions provided therein were tailored to the specific research questions, for the questions addressing: (1) consideration of potential confounders, (2) confidence in the exposure characterisation, and (3) confidence in the outcome assessment (Appendix B).	
• if yes, what tools are used? if no, was any other method used to assess study quality?		Office of Health Assessment and Translation (OHAT) RoB tool developed by the US National Toxicology Program (NTP) (OHAT-NTP, 2015)	

Criteria	Yes/No/ NA	Comment	Page #
Does the organisation use a systematic or some other methodological approach to synthesise the evidence (i.e. to assess and summarise the information provided in the studies)?	Yes	Use of forest plots where possible – Q2, 3 and 5	
Does the organisation assess the overall certainty of the evidence and reach recommendations?	Yes	The overall body of evidence is assessed for each outcome. The OHAT RoB tool proposes five response options for each RoB question: definitely low RoB (++), probably low RoB (+), not reported (NR), probably high RoB (−), definitely high RoB (−−). For the appraisal of intervention studies, the scale was aggregated to three options (high RoB, NR, low RoB) as it was considered sufficiently discriminatory for this design in the context of the present assessment. Studies were categorised according to their overall RoB based on a three-tier system (i.e. at low (tier 1), moderate (tier 2) or high (tier 3) RoB), according to the strategy proposed by OHAT (OHAT-NTP, 2019) (Appendix B)	

Derivation of nutrient reference values

Criteria	Yes/No/ NA	Comment	Page #
Is the method selected to calculate NRV(s) documented and justified? (factorial, dose response or risk assessment)	Yes	Questions were risk assessment based. A dose-response meta-analysis on selenium exposure and incidence of T2DM was performed.	
Are the algorithms and calculations clearly documented and explained?	Yes	Yes there is reference to formulae in the EFSA 2022 NDA Panel document.	10
Are the assumptions and reference data (intake, body weights for age groups etc) used for the calculations clearly documented and explained?		The reference weights are based on WHO data. Allometric scaling is currently used for the 2006 NRVs on selenium UL and is appropriate.	

Criteria	Yes/No/ NA	Comment	Page #
Is there justification for the choice of uncertainty and safety factors?	Yes	Considering that alopecia is an early sign of selenium toxicity, is of mild nature and likely to be reversible, the Panel considers that an UF of 1.3 is sufficient to cover for the uncertainties. For adults no UF is applied as the population is representative given the large numbers in the studies.	75
Are the selected endpoints appropriate? Is justification provided for any clinical/chronic endpoints selected as indictors/outcomes? (Details of endpoints to be provided in a supplementary table.)	Yes	Based on considerations of causality and biological relevance, the Panel selects alopecia as the critical endpoint on which to base a UL for selenium. A NOAEL and LOAEL was established as the reference point. Alopecia is an early observable feature and a well-established adverse effect of excess selenium exposure (Sections 3.5.2.1 and 3.5.2.2). Thus, based on considerations of causality and biological relevance, the Panel selects alopecia as the critical endpoint on which to base a UL for selenium (Section 3.6.2). The panel selected incidence of type 2 diabetes as the key endpoint for the comprehensive uncertainty analysis.	
Is justification provided for the value selected for the reference point^? (including mechanistic evidence, health outcome data, key events, balance studies) ^ reference point is usually the baseline value to which any scaling and uncertainty factors are applied.	Yes	There are indications from one RCT, the SELECT (Lippman et al., 2009), that at average selenium intakes of 330 µg/day (around 130 µg/day from the background diet plus 200 µg/day from supplements), the risk of developing alopecia is increased as compared to un-supplemented individuals with similar background selenium intakes. This was accompanied by an increased risk of other features of selenium toxicity, such as dermatitis (Section 3.5.2.2). The Panel uses the LOAEL of 330 µg/day identified from the SELECT as a RP for the derivation of an UL for selenium.	

Criteria	Yes/No/ NA	Comment	Page #
Is the population group generalisable to the Australian and New Zealand population? - Where are the underlying studies from	Yes	The Panel notes that men aged ≥ 50 years, recruited from the general population in the US, were involved in the SELECT. There is no indication from the literature that younger men may be more susceptible to selenium toxicity. The Panel considers that the results from the SELECT can be generalised to the European male adult population and that the LOAEL of 330 µg/day derived from that study is applicable to this population group.	
If scaling was applied – was the method described, along with an appropriate rationale for the chosen method?	Yes	The rationale for scaling for children and infants is described (allometric scaling using WHO reference data).	
• Is the method used appropriate for Australian and New Zealand populations?	Yes	The reference weights are based on WHO data and allometric scaling is currently used for the 2006 NRVs on selenium ULs.	
Are the processes used when expert judgement is applied documented and published? (Evidence to decision process used to obtain final conclusions).	Yes	The Panel has recorded decisions made with regards to the rationale and feasibility of the new values.	

Suitability for adopting vs adapting

Criteria	Yes/No/ NA	Comment	Page #
How does the Australian and New Zealand context (e.g. food system, dietary patterns, intakes, status) compare with the jurisdiction in which the NRV under consideration was developed?		It is broadly similar both in the types of foods available and available data on intake levels of selenium. European intake data is only slightly higher than Australian data which was last estimated in the 2011-12 nutritional survey. Across population groups, the main food groups contributing to selenium intake were milk and dairy products, meat and meat products, grains and grain-based products and fish and fish products, with minor differences between sexes (EFSA NDA Panel, 2014) (Annex C).	

Appendix B – Evidence-to-Decision Frameworks

Selenium – Upper Levels

Background

Rationale for prioritising this update

NHMRC published its current selenium NRVs in 2006 (NHMRC, 2006), the values were adopted from the 2000 US Institute of Medicine (IOM) values (IOM, 2000). In 2023, European Food Safety Authority (EFSA) updated their UL for selenium (EFSA, 2023) based on a large RCT (Lippman et al. 2009). In 2025 NHMRC published their updated health-based guideline value for selenium levels in drinking water (NHMRC, 2025a) based on the same RCT. Therefore, updating the NHMRC NRV UL for selenium supports consistency both within the NHMRC, and internationally.

In addition, NHMRC was seeking to pilot process for updating NRVs by adopting or adapting recommendations from other comparable jurisdictions to make the most effective and efficient use of limited resources and reduce duplication of effort. Updating selenium was an opportunity to develop and test these methods. The NHMRC Steering Group Advisory Committee assessed the updated EFSA selenium UL against formal criteria and found it suitable for adapting to the Australian and New Zealand context ('**Appendix A** - Administrative and technical criteria for assessing existing nutrient reference values for adopting or adapting').

Selenium – function and dietary sources

Function

Selenium is an essential mineral that plays a vital role in various metabolic processes, including antioxidant activities, thyroid hormone metabolism, and DNA synthesis (Alexander & Olsen 2023). It further supports reproductive health and immune function.

Food

Food is the primary source of selenium for humans, while drinking water and air contribute only minor amounts (Barceloux 1999). The food with the highest selenium concentration is Brazil nuts, with an average of 575 µg per 30g, followed by mustard powder (48 µg per 30g) and yelloweye mullet (33 µg per 30g) (FSANZ, 2022).

The main dietary contributors to selenium intake for the Australian population, including children and teenagers, are meat, poultry, fish, seafood and game products, along with cereal-based products and dishes (Australian Bureau of Statistics 2019). In New Zealand the main dietary contributors are bread, fish/seafood, poultry, eggs, grains/pasta, and pork for adults (University of Otago & Ministry of Health 2011), while fish and seafood is the most significant source of selenium for children, followed by poultry, bread and grains/pasta (Ministry of Health 2003).

The amount of selenium in cereal-based foods is directly affected by the selenium content of the soil where it was grown (Tinggi 2003). The soil selenium levels are highly variable in Australia and New Zealand, therefore dietary intake of selenium from cereal-based foods differs geographically (Lymbury et al. 2008; Thomson 2004).

Selenium (in the forms of selenomethionine, sodium selenate or sodium selenite) is permitted to be added to formulated beverages, meal replacements, supplementary sports foods, and foods for special medical purposes (Australian Government 2021, 2025c). There are no regulatory requirements to add selenium to food in Australia or New Zealand (except infant formula).

Supplements

The 2023-24 Australian National Nutrition and Physical Activity Survey found that 33.6% of people aged two-years and over, and 37.3% of adults (18-years and over) took a dietary supplement in 2023; 15.5% of the population took a multivitamin or multimineral supplement (17.0% for adults), and 0.7% of the population aged two-years and over (0.8% of adults) took an 'other single mineral supplement' (ABS 2025), there were no specific figures for the use of selenium-only supplements. In New Zealand, the 2008–09 Adult Nutrition Survey (University of Otago & Ministry of Health 2011) found that 47.6% of people aged 15-years and over took a supplement in the past year, with 30.7% being regular users; 10.6% of men and 18.6% of women consumed multivitamin and multimineral supplements, 3.0% of men and 8.5% of women consumed single mineral supplements, and 1.0% of men and 2.1% of women consumed multimineral supplements. There are no specific data available regarding the use of selenium-only supplements. According to the Therapeutic Goods Poisons Standard (Australian Government 2025a, 2025b), selenium is classified as a Schedule 2 (pharmacy medicine) except for oral preparations with a recommended daily dose of 150 µg or less, and as a Schedule 4 (prescription only medicine) for oral human use with a recommended daily dose exceeding 300 micrograms.

Bioavailability factors

Various methods have been used to measure selenium bioavailability, including changes in blood (including plasma, serum and erythrocytes) selenium concentration, GPx enzyme activity, and absorption/retention studies using stable isotopes (Fairweather-Tait & Collings 2010).

Selenium is well absorbed from dietary sources, (approximately 70-80% absorption rate) (Burk & Hill 2015; Lei et al. 2022), but only a little over half is retained in the body (Alexander & Olsen 2023). All forms of selenium enter the selenide pool, where they are either used for selenoprotein synthesis or excreted as selenosugar in the urine (Fairweather-Tait & Collings 2010). Most selenium forms are efficiently absorbed, but utilisation differs depending on their plasma form. While the absorptive pathways are not fully understood, inorganic forms of selenium (selenate, selenite) are well absorbed but less retained compared to organic forms (selenomethionine, selenocysteine) (Burk et al. 2006; Schrauzer 2000). This has been demonstrated in the results of human studies of selenium metabolism from various foods and supplements (Brown et al. 2000; Butler et al. 1991).

Plants accumulate inorganic forms of selenium through soil and ground water and convert to organic forms, with selenomethionine being more readily absorbed and retained than inorganic forms (Hadrup & Ravn-Haren 2021). Selenium from meat (primarily selenomethionine) and Brazil nuts is used effectively by the body (Thomson et al. 2008). The organic compound γ-glutamyl methylselenocysteine, found in brassica and allium vegetables, is metabolised differently and mainly excreted in breath and urine (Rayman et al. 2008).

Although there is no evidence that current levels of selenium intake in Australia or New Zealand are associated with any health problems in the general population, 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.

Health effects of excess

Acute selenium poisoning (acute selenosis) presents with symptoms such as hypotension, tachycardia, nausea, vomiting, diarrhoea, abdominal pain, and pulmonary oedema. Neurological symptoms can include tremors, muscle spasms, restlessness, confusion, delirium, and even coma (Fairweather-Tait & Collings 2010; Nuttall 2006).

The most common signs of chronic selenosis include brittle, thickened nails with spots and streaks, brittle hair, and alopecia. Other symptoms include tooth discoloration and decay, a garlic odour on the breath, skin lesions, and neurological issues such as fatigue, weakness, peripheral paraesthesia, hyperreflexia, pain in the extremities, unsteady gait, paralysis, and decreased cognitive function (Fairweather-Tait & Collings 2010; NHMRC 2006; Nuttall 2006; Rayman et al. 2008).

While several population groups are at greater risk of suboptimal selenium status (i.e. during pregnancy, cigarette smokers, people living in regions with low soil selenium levels or with inflammatory conditions) the groups that may be at greater risk of excess selenium consumption or the associated health effects are regular consumers of Brazil nuts, and consumers of selenium containing supplements.

Criteria for measuring selenium intake and status

There are limitations in the accuracy of dietary selenium intake assessment methods, including concerns about reporting bias (including social desirability bias), variability of selenium content in foods, and the accuracy of food composition data. It is also difficult to ascertain individual status based on dietary intakes which reflect intakes at a specific point in time and fail to account for selenium stores. Biomarkers that are used to measure short-term selenium intake include urinary selenium and plasma selenium levels, while erythrocytes are used to measure medium-term intake (Combs 2015). Long-term selenium status can be measured by toenail and hair selenium concentrations. Measurement of selenoproteins (i.e. GPx and selenoprotein P) are useful to assess functional selenium status, but their utility is limited to selenium intakes below 60 – 70 µg/day.

All selenium biomarkers are affected by various physiological and lifestyle factors, including age, sex, disease status, inflammation and smoking.

Comparison of intake data between Australia, New Zealand and EFSA should be interpreted with caution as intake values are derived from different surveys, different food composition tables and databases, represent different years, and are reported for different age groups. Furthermore, intake estimates from Australia included food and supplements, while New Zealand and EFSA presented intakes from food only.

Evidence to decision tables – selenium UL

Adults

	OPTION 1: *Retain* the current UL for adults	**OPTION 2:** *Adapt* EFSAs 2023 UL for adults to the Australian and New Zealand context
Example recommendation	<table><tr><th>Age</th><th>UL (µg/day)</th></tr><tr><td>18+ years</td><td>400</td></tr></table> UL applies to both sexes, and during pregnancy and lactation.	<table><tr><th>Age</th><th>UL (µg/day)</th></tr><tr><td>18+ years</td><td>330</td></tr></table> UL applies to both sexes, and during pregnancy and lactation Based on the intake data for the Australia (2011-2012) and New Zealand (2008-2009) populations it is unlikely that most of the general adult population will exceed this UL. Those most at risk are regular users of high-dose selenium supplements, and regular consumers of Brazil nuts, due to their high selenium content.
Health evidence profile and supporting information	The 2006 NHMRC selenium ULs were adopted from the 2000 US Institute of Medicine (IOM) ULs. Based on considerations of causality, relevance, and the quality and completeness of their database, the IOM selected hair and nail brittleness and hair loss as the critical endpoints on which to base their ULs due to the frequency of reporting of these symptoms of chronic selenosis. They considered biochemical markers to be too variable/unreliable except under controlled conditions. A NOAEL of 850 µg/day was selected, based on a cross-sectional study of 349 individuals (age 1–71 years) living in areas with 'low', 'medium' or 'high' soil selenium concentration in China (Yang et al. 1989). A total of 60 cases of selenosis (aged 13–70 years) were identified. Selenosis was diagnosed by morphological changes in fingernails with or without hair loss or	The evidence underpinning EFSA's 2023 selenium UL was a single, large RCT (roughly 8,700 per arm) of selenium supplementation (200 µg/day) vs placebo, with a median follow-up of 5.5 years (Lippman et al. 2009). Participants were healthy men aged ≥50 years in the USA. The study's primary endpoint was prostate cancer, with adverse effects - including the critical end point of alopecia - recorded every 6 months. The study found that at average selenium intakes of 330 µg/day (around 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, EFSA selected a LOAEL of 330 µg/day as the reference point for the revised selenium UL.

	changes in hair structure. No clinical signs of selenosis were observed among individuals with whole blood selenium concentration <1,000 µg/L, corresponding to selenium intakes of around 850 µg/day selenium (as calculated by the authors). A follow-up study among five cases with long-persisting clinical symptoms of selenosis found that symptoms disappeared after a change in diet resulting in lower selenium intakes (Yang and Zhou, 1994, as cited by EFSA, 2023). This value was consistent with the findings of a US study (Longnecker et al 1991, as cited by IOM, 2000). An Uncertainty factor (UF) of 2 was applied to protect sensitive individuals because of gaps in data and incomplete knowledge, bearing in mind that the toxic effect of selenium was thought to be not severe but potentially irreversible. The UL set for adults was used for pregnancy and lactation as there were no data to suggest increased susceptibility during these life stages.	Alopecia was considered suitable as the critical effect as it was considered a well-established, early observable effect of excess selenium intake. EFSA applied a UF of 1.3 to the reference point to account for the use of a LOAEL in place of a NOAEL (but they considered the NOAEL might be close to the LOAEL), and the lack of data in women (however, there is no evidence that women are more sensitive than men to selenium toxicity). The result was rounded to the nearest 5 µg to establish a UL of 255 µg/day for adults (including during pregnancy and lactation). To adapt the EFSA UL to the Australian and New Zealand context, a UF of 1 was applied to the reference point (LOAEL of 330 µg/day), to establish a UL of 330 µg/day for adults. The UF of 1 was a pragmatic decision based on the judgement of Australian and New Zealand experts. This UF was selected due to: - the mild and reversible nature of alopecia as an end point - the likelihood that the LOAEL was close to the NOAEL and a lack of evidence for adverse effects at intakes below the proposed UL - the robustness of the evidence-base (particularly in comparison with evidence upon which existing UL recommendations are based). Consideration was also given to ensuring an adequate buffer between the proposed UL and the EAR and RDI, and usual population intakes in Australia and New Zealand. A UL of 330 µg/day better aligns with most recent evidence without lowering it to a level where the proportion of the population that exceeds the UL without demonstrating symptoms increases significantly.
Selenium exposure in Australia and New Zealand **General population**	The selenium intake data for adults in Australia (2011-12) and New Zealand (2008-09) are presented in Table 4 and Table 5. These data show that 95th percentile selenium intakes from food and supplements in Australia and 90th percentile intakes from food only in New Zealand are lower than the proposed ULs of 400 µg/day (option 1) or 330 µg/day (option 2) for adults across all age groups. Less than 5% of the Australian population exceeded the (2006) UL for selenium (ABS 2011). The percentage of the population exceeding the proposed ULs or 90th percentile in New Zealand is not available.	

TABLE 17. Selenium intake in Australian adults (general population), 2011-12 Australian Health Survey

Age groups (years)	Sex	Mean Intake (µg/day)	% less than EAR	95th percentile intake (µg/day)
19-30	Males	110	1.4%	160
	Females	77	6.4%	114
31-50	Males	105	2.3%	153
	Females	79	5.4%	117
51-70	Males	97	4.3%	143
	Females	80	4.9%	118
71 and over	Males	85	12.2%	125
	Females	72	10.4%	107

Source: https://www.abs.gov.au/statistics/health/health-conditions-and-risks/usual-nutrient-intakes/latest-release
Abbreviations: CI, confidence interval; EAR, estimated average requirement; UL, upper level.

TABLE 18. Selenium intake in New Zealand adults (general population), 2008-09 New Zealand Adult Nutrition Survey

Age groups (years)	Sex	Mean Intake (µg/day)	% less than EAR	90th Percentile intake (ug/day)
15-18	Males	66.6	40.4%	91.0
	Females	41.1	78.2%	59.0
19-30	Males	67.6	29.7%#	84.7
	Females	47.1	71.7%	57.6
31-50	Males	79.4	10.9%#	102.0
	Females	54.2	43.8%	73.8
51-70	Males	63.8	46.8%	87.0
	Females	52.3	55%	82.0
71 and over	Males	56.9	63.8%	87.0
	Females	41.6	58.2%	58.2

Source: https://www.health.govt.nz/system/files/2011-10/a-focus-on-nutrition-v2.pdf

	Abbreviations: CI, confidence interval; EAR, estimated average requirement; *nr*, not reported; UL, upper level. [#] Coefficient of variation of estimated inadequate intake is greater than 50% and confidence interval lies outside range (0–5%). Estimate should be interpreted with caution due to the high level of imprecision relative to the estimate. **Highest intake** The population with the highest intake overall was New Zealand 31–50-year-old Pacific males, with a 90th percentile intake of (194 µg/day, food only), followed by Australian 19–30-year-old males, with a 95th percentile intake of 160 µg/day (food and supplements). These estimated intakes are lower than both the current NHMRC selenium UL (400 µg/day) and adapted EFSA selenium UL (330 µg/day). **Supplements** - The Therapeutic Goods Administration (TGA) Poisons Standard (Australian Government 2025a, 2025b) regulates selenium as a Schedule 2 (pharmacy medicines) except for products for human oral use with a recommended daily dose of 150 µg or less, and under Schedule 4 (prescription only medicines) for human oral use with a recommended daily dose of more than 300 micrograms. - No data are available specifically related to selenium supplement use in Australia or New Zealand **Food supply** The Australia New Zealand Food Standards Code permits selenium to be added up to a maximum of: • formulated beverages – 17.5 µg/600mL • formulated meal replacements - 17.5 µg/serve inorganic, 9 µg/serve organic • formulated supplementary sports foods - 52 µg/serve inorganic, 26 µg/serve organic • food for special medical purposes represented as a sole source of nutrition - 25 µg/MJ (Australian Government 2021, 2025c). There are no regulatory requirements to mandate the addition of selenium to food in Australia or New Zealand (except infant formula).

Selenium exposure in Australia and New Zealand
 	
Special populations
	Aboriginal and Torres Strait Islander Australians and other cultural populations
	
	There is no evidence to suggest that special considerations are needed for Aboriginal and Torres Strait Islander, Māori or Pacific populations.
	
	Selenium intakes are generally similar between Aboriginal and Torres Strait Islander Australians and non-Indigenous Australians.
	
	Australia, comparison of Aboriginal and Torres Strait Islander Australians and non-Indigenous populations
	
	- Mean selenium intake estimates for Aboriginal and Torres Strait Islander Australians and non-Indigenous Australians were similar:
	  o Aboriginal and Torres Strait Islander Australians: 49.9-92.9µg/day,
	  o non-Indigenous Australians: 47.0–93.5 µg/day).
	- Excess intake: There was no information on the proportion of the Australian Aboriginal and Torres Strait Islander population exceeding the UL for selenium (less than 5% of the non-Indigenous population exceeded the UL).

- Data source: Australian Aboriginal and Torres Strait Islander Health Survey: Nutrition Results - Foods and Nutrients, 2012-13

New Zealand

- Mean selenium intake was higher in the Pacific and Māori populations than the 'European and other' population
  - Māori population: 33.7-69.1 µg/day *(mean of male and female values)*
  - Pacific population: 31.8-84.5 µg/day *(mean of male and female values)*
  - 'European and other' population: 25.5-64.7 µg/day *(mean of male and female values)*
- Excess intake: there was no information on the proportion exceeding the UL for selenium for any population in New Zealand.
- The group with the highest intake overall was the 31–50-year-old New Zealand male Pacific population (90th percentile intake of 194 µg/day), which is lower than the current selenium ULs from NHMRC (400 µg/day) and adapted EFSA (330 µg/day).
- Data source: 2008-09 New Zealand Adults Nutrition Survey

Pregnancy and lactation

- There is no evidence that special considerations are needed during pregnancy and lactation.
- EFSA's Selenium UL recommendations apply to all adults (including people who are pregnant or lactating).

Sex considerations

- There is no evidence that special considerations are needed in relation to sex.
- EFSA's ULs apply to entire age groups for adults, they are not differentiated by sex. This is consistent with NHMRCs 2006 ULs.

Benchmarking against comparable international jurisdictions

Proposed Upper Level (UL) recommendations for adults are presented below in Table 19 alongside ULs from comparable international jurisdictions.

The UL for adults is consistent between Australia and New Zealand, the USA, and WHO at 400 µg/day, and the UK value is slightly higher at 450 µg/day. It should be noted, however, that these values are more than 20-years old.

In 2023, the adult UL for Europe was lowered from 300 µg/day to 255 µg/day.

TABLE 19. Adult selenium UL recommendations across comparable international jurisdictions

Jurisdiction	Australia & New Zealand		Europe (current)	Europe (previous)	USA	UK	International
	Option 1: RETAIN NHMRC (2006)	Option 2: ADAPT Adapted EFSA value	EFSA (2023)	SCF (2000)	IOM (2000)	EVM (2003)	WHO/FAO (2004)
UL (µg/day)	400#	330#	255#	300#	400	450	400

	Abbreviations: EVM, UK Expert Group on Vitamins and Minerals (UK); IOM, Institute of Medicine (US); NHMRC, National Health and Medical Research Council; SCF, Scientific Committee on Food; WHO/FAO, World Health Organization/Food and Agriculture Organization of the United Nations; UL: upper level. [#] Including pregnant and lactating women.	
Balance of effects (benefits and harms)	It is unclear whether the current UL of 400 µg/day is protective of most individuals in the general population of Australia and New Zealand as intakes for most population are significantly lower that this level. There is no evidence to suggest that acute or chronic selenosis are public health concerns in Australia or New Zealand.	The proposed UL of 330 µg/day is expected to be protective of most individuals in the general population of Australia and New Zealand. In Australia and New Zealand there is a relatively low risk of selenium toxicity due to moderate selenium levels in soil and food supply. Certain regions (such as central Queensland) have selenium-rich soils. Overall dietary selenium intake appears to remain within safe limits for most of the population, as no evidence of excess intakes was identified. There is no evidence to suggest that acute selenosis, chronic selenosis, or alopecia as an early marker of selenosis are public health concerns in Australia or New Zealand. There is no evidence that specific populations are more sensitive to selenium, at greater risk of excess or more susceptible to the health effects associated with excess consumption. People most likely to develop selenosis are those who regularly consume Brazil nuts or take supplements at levels significantly higher than the UL. **Benefits of adapting EFSA's reduced UL 330 µg/day:** • Aligns with international best practice based on evidence from a large higher certainty RCT (Lippman et al 2009) • Provides potentially enhanced protection against early markers of selenium toxicity (alopecia) before more serious health effects occur • Ensures harmonised standards with comparable international jurisdictions • Offers an additional margin of safety through precautionary approach • Provides additional evidence to strengthen supplement regulation and consumer guidance for high-risk consumption patterns **Potential harms/considerations:**

		• May represent a more restrictive approach than currently warranted by the Australian and New Zealand context, where selenium toxicity risk is relatively low due to moderate selenium levels in soil and food supply **Current risk context:** In Australia and New Zealand, overall dietary selenium intake remains within safe limits for most of the population, with certain regions (i.e. central Queensland) having selenium-rich soils. There is currently no evidence that acute selenosis, chronic selenosis or alopecia are public health concerns in the general population. No specific population has been identified as being more sensitive to selenium. The population group at greatest risk of excess consumption is the group with the highest selenium intake level – the male New Zealand Pacific population, 31–50 years (90th percentile intake of 194 µg/day, from food only). Other groups most likely to approach or exceed upper levels are those who regularly consume Brazil nuts or take supplements, making the evidence-based UL reduction particularly relevant for protecting those consumers from potential adverse effects. It should be noted that there is no recent nationally representative information on selenium intakes in Australia or New Zealand currently available. Intake may have increased since the last national nutrition surveys in 2011/12 and 2008/09, respectively. There is no evidence that harm from excess consumption of selenium is occurring in Australia or New Zealand with the current UL of 400 µg/day. However, this may be due to habitual intakes not approaching the level of the UL, rather than suggesting that the UL of 400 µg/day is sufficiently protective. The large RCT identified by EFSA (Lippman et al. 2009) gives a more reliable estimate of the level at which harm has the potential to occur in adults (330 µg/day) compared to the 1989 cross-sectional study (n=349) upon which current UL recommendations are based
Certainty of the evidence	The reference point came from a cross-sectional study of 349 individuals (age 1–71 years) living in areas with 'low', 'medium' or 'high' soil selenium concentration in China (Yang et al. 1989), with 60 cases of selenosis (aged 13–70 years) identified. Whole blood selenium concentration and its	Evidence appraisal of the SELECT trial (Lippman et al. 2009) was performed using the Office of Health Assessment and Translation (OHAT) Risk of Bias tool developed by the US National Toxicology Program (NTP) (OHAT-NTP, 2015, as cited by EFSA, 2023), as it is more suited to toxicology and risk assessment applications.

	corresponding intakes (as calculated by the authors) were used to establish a NOAEL. A follow-up study, among five cases with long-persisting clinical symptoms of selenosis found that symptoms disappeared after a change in diet resulting in lower selenium intakes (Yang and Zhou, 1994, as cited by EFSA, 2023). This value was consistent with the findings of a US study (Longnecker et al 1991, as cited by IOM, 2000). The evidence underpinning current recommendations is limited by concerns about: - observational study design (cross section and case-study data) - imprecision (small sample sizes) - generalisability: studies conducted in people in China, who may be either more or less sensitive to selenium than other populations - heterogeneity: wide-ranging age group (1-77 years).	EFSA did not assess the risk of bias for the outcome of alopecia, but when assessed for the outcome of Type 2 Diabetes (which was a pre-specified primary outcome), the study was found to have a *low risk of bias*. The EFSA Panel noted strengths of the study were: - controlled setting regarding selenium intake (fixed supplemental dose, high level of compliance among participants) - large sample size and its long duration. Uncertainties related to deriving an UL from the study include: - self-reporting of adverse events (however, the signs and symptoms of selenosis recorded were pre-planned adverse events that were monitored using standardised criteria) - use of a LOAEL in place of a NOAEL (however, they considered the NOAEL might be close to the LOAEL) - lack of evidence in women (however, there is no evidence that women are more sensitive than men to selenium toxicity). The selenium toxicity findings of the Lippman study were not replicated in three other smaller RCTs at similar or higher levels of selenium intake (Algotar et al. 2013; Thompson et al. 2016; Winther et al. 2015); however, the smaller RCTS were considered to provide limited information on the method used to identify adverse events and may have lacked sufficient power to detect such effects. Overall, EFSA considered the SELECT trial (Lippman et al. 2009) to be the best available evidence upon which to base an updated UL.
Values, preferences and feasibility (consumers, communities)	Selenium intake data shows that New Zealand tends to have lower intakes than Australia. Dietary modelling data indicate that selenium intakes among adults in both Australia and New Zealand consistently fall below both current and proposed ULs, with approximately 30% of model intakes below the current RDI (male RDI: 70 µg/day, female RDI: 60 µg/day; Table 20). The average model intake (~70 µg/day) is significantly lower than the adapted EFSA UL (330 µg/day) and the current NHMRC UL (400 µg/day). This pattern is consistent across pregnant and lactating populations, who use the same adult UL values (Table 21). This suggests that a reduction in the UL would be safe and feasible. While modelling relied on incomplete data and interpolation, intake patterns align with empirical survey findings from Australia and New Zealand (Tables 17 & 18), supporting the reliability of the estimates. Overall, both modelled and measured intakes support the feasibility of	

implementing a lower UL without requiring dietary changes. Supplement intake at levels consistent with unscheduled over the counter products for human consumption (<150 µg/day) is unlikely to be impacted.

TABLE 20. Food modelling data in adults, Modelled Selenium Intake (µg/day)

Age Group (years)	Core Food Groups	Foundation Diet		Rice-based		Pasta-based		Lacto-ovo-veg	
	Both sexes	Male	Female	Male	Female	Male	Female	Male	Female
19-30		87	75	72	80	81	92	73	58
31-50	39	91	78	74	84	83	96	75	61
51-70		81	73	71	58	79	62	66	54
70+		77	65	67	54	74	55	63	48

Source: A modelling system to inform the revision of the Australian Guide to Healthy Eating (Baghurst et al. 2011)
Abbreviation: veg, vegetarian.

TABLE 21. Food modelling data in pregnant and lactating populations, Modelled Selenium Intake (µg/day)

Age Group (years)	Foundation Diet	
	Pregnancy	Lactation
14-18	116	93
19-30	111	90
31-50	115	94

Source: A modelling system to inform the revision of the Australian Guide to Healthy Eating (Baghurst et al. 2011)

Resource impacts

Retaining the current values for adults has no material implications. Adult age groupings are being adjusted to align with new age groups. The adult NRVs are the same for all age groups so there is no material impact of this change. Consequently, this minor change to age groupings should have no implications for regulators, including FSANZ (food and food products) and TGA (supplements).

The proposed change to the UL is unlikely to have significant implications for regulators, including FSANZ (food and food products) and TGA (supplements). Views will be sought during targeted/stakeholder consultation and considered when developing final NRVs.

The Australia New Zealand Food Standards Code permits selenium to be added up to a maximum of:

- formulated beverages – 17.5 µg/600mL
- formulated meal replacements - 17.5µg/serve inorganic, 9 µg/serve organic
- formulated supplementary sports foods - 52 µg/serve inorganic, 26 µg/serve organic

		• food for special medical purposes represented as a sole source of nutrition - 25 µg/MJ At normal levels of consumption these products are unlikely to contribute to exceeding the UL if it is lowered to 330 µg/day. At normal levels of intake over-the-counter supplements (<150 µg/day) are unlikely to contribute to exceeding the UL if it is lowered to 330 µg/day. The exception is the higher-level selenium consumers in the New Zealand Pacific males aged 31-50 years, with a 90th percentile of 194 µg/day (from food only), where supplementation of 137 µg/day or above would exceed this UL.
Other factors (health equity impacts, sustainability)	The UL should aim to be protective of almost all individuals within the population. Maintaining the UL of 400 µg/day should continue to protect most individuals from the health effects of selenium excess.	The UL should aim to be protective of almost all individuals within the population. Reducing the UL to 330 µg/day should continue to protect most individuals from the health effects of selenium excess.
Decision	*Adapt EFSAs 2023 UL to the Australian and New Zealand context, reducing the UL to 330 µg/day for all adults (including during pregnancy and lactation).*	

Children and adolescents

<table>
<tr><th></th><th><u>OPTION 1</u>:
Retain the current ULs for adults and children</th><th><u>OPTION 2</u>:
Adapt EFSAs 2023 UL for adults and extrapolate for children</th></tr>
<tr><td>Example recommendation</td><td>
NRV age groups
<table>
<tr><th>Age</th><th>UL (µg/day)</th></tr>
<tr><td>0-6 months</td><td>45</td></tr>
<tr><td>7-12 months</td><td>60</td></tr>
<tr><td>1 to under 4 years</td><td>90</td></tr>
<tr><td>4 to under 9 years</td><td>150</td></tr>
<tr><td>9 to under 14 years</td><td>280</td></tr>
<tr><td>14 to under 18 years</td><td>400</td></tr>
</table>
Alternative age groups for preschool, primary school and adolescents
<table>
<tr><th>Age</th><th>UL (µg/day)</th></tr>
<tr><td>12 to under 24 months</td><td>90</td></tr>
<tr><td>2 to under 5 years</td><td>110</td></tr>
<tr><td>5 to under 12 years</td><td>205</td></tr>
<tr><td>12 to under 18 years</td><td>360</td></tr>
</table>
ULs apply to both sexes, and during pregnancy and lactation.
</td><td>
NRV age groups
<table>
<tr><th>Age</th><th>UL (µg/day)</th></tr>
<tr><td>0-6 months</td><td>45*</td></tr>
<tr><td>7-12 months</td><td>60*</td></tr>
<tr><td>1 to under 4 years</td><td>100</td></tr>
<tr><td>4 to under 9 years</td><td>150</td></tr>
<tr><td>9 to under 14 years</td><td>235</td></tr>
<tr><td>14 to under 18 years</td><td>305</td></tr>
</table>
* values for infants retained - not reviewed in this update.
Alternative age groups for preschool, primary school and adolescents
<table>
<tr><th>Age</th><th>UL (µg/day)</th></tr>
<tr><td>12 to under 24 months</td><td>85</td></tr>
<tr><td>2 to under 5 years</td><td>120</td></tr>
<tr><td>5 to under 12 years</td><td>185</td></tr>
<tr><td>12 to under 18 years</td><td>295</td></tr>
</table>
</td></tr>
</table>

	For children the UL values are based on the same evidence as the NHMRC 2006 values. UL values for infants and children have not been updated. Additional child age groupings have been calculated based on weighted averages to include school age groups for reporting against the 2025 ABS National Health survey. UL values the 12 to under 24-month population have been extrapolated from adult data using WHO growth charts (WHO 2006), as ABS does not collect information on these age groups.	ULs apply to both sexes and values for children aged 1 year and above have been extrapolated from the adult UL using updated ABS reference weights for each group (NHMRC 2025b). Additional child age groupings have been calculated to include school age groups for reporting against the 2025 ABS National Health survey. UL values for infants were not within the scope of this review and remain as established in 2006. These values are based on a study showing no adverse effects at breast milk selenium concentrations of 60 µg/L (Shearer & Hadjimarkos 1975). Based on the most current intake data for the Australian and New Zealand populations, excess intake is unlikely *(see section below: Selenium exposure in Australia and New Zealand).* Most at risk of exceeding the UL of intake are regular consumers of Brazil nuts (due to their high selenium content), and high consumers of selenium supplements (especially those sourced from overseas which may have selenium levels higher than those permitted by the TGA).
Health evidence profile and supporting information	The 2006 NHMRC selenium ULs were adopted from the 2000 US Institute of Medicine (IOM) ULs (Institute of Medicine Panel on Dietary & Related 2000). The UL for young infants was based on the studies of Shearer & Hadjimarkos (1975). Data on selenium breast milk concentration was collected from 241 participants across the United States. Results suggested that a breast milk concentration of 60 µg/L was not associated with adverse effects. This gives a NOAEL of 47 µg/day (7 µg/kg body weight).	As there was no data to support the derivation ULs for children, and there is no evidence to indicate that children may be more susceptible to selenium toxicity than adults, the adapted EFSA selenium ULs for adults were extrapolated to children. Allometric scaling with reference bodyweights was used to derive a UL for each age group. *For further information on the evidence supporting the Adult UL, see the Adult Evidence-to-Decision table*

	A UF of 1 was applied, as there is no evidence that maternal intakes associated with breast milk in this range cause toxicity for mothers or infants (Shearer & Hadjimarkos 1975). As there was no evidence of increased toxicity in older children and adolescents, the ULs for these groups were scaled up from the younger infant data using the level of 7 µg/kg body weight. Values were rounded down to the nearest 5µg.	

Selenium exposure in Australia and New Zealand

General population

Children

The most current intake data for Australian and New Zealand Children are presented in **Table 22** and **Table** 23.

These data show that selenium intakes are well below the proposed retained or adapted ULs for at least 95% of children across all age groups (see *Example Recommendations* above).

TABLE 22. Selenium intake in Australian children, 2011-12 Australian Health Survey

Age groups (years)	Sex	Mean intake (µg/day)	% less than EAR	95th percentile intake (µg/day)
2-3	Males	49	0%	65
	Females	45	0%	59
4-8	Males	61	0%	80
	Females	55	0%	72
9-13	Males	80	0.9%	118
	Females	69	3.0%	103
14-18	Males	96	5.0%	140
	Females	73	9.7%	109

Source: https://www.abs.gov.au/statistics/health/health-conditions-and-risks/usual-nutrient-intakes/latest-release

Abbreviations: CI, confidence interval; EAR, estimated average requirement; UL, upper level.

TABLE 23. Selenium intake in New Zealand children, 2002 New Zealand Children's Nutrition Survey

Age groups (years)	Sex	Mean intake (µg/day)	% less than RNI[#]	90th Percentile intake (ug / day)
5-6	Males	31.0	*nr*	42.5
	Females	25.5	*nr*	33.9
7-10	Males	37.4	*nr*	54.3
	Females	33.1	*nr*	50.9
11-14	Males	49.3	*nr*	81.0
	Females	35.8	*nr*	45.8

Source: https://www.health.govt.nz/system/files/2011-11/nzfoodnzchildren.pdf

Abbreviations: CI, confidence interval; EAR, estimated average requirement; nr, not reported; UL, upper level.

For this survey, comparisons of New Zealand children's usual daily median intakes of selenium with recommendations are difficult as the age grouping in this survey differs from that used for the 2001 selenium RNI for the New Zealand population (Thomson and Paterson 2001, as cited by Ministry of Health, 2003) Overall, the reported results suggested New Zealand children, especially older children, were at risk of having inadequate selenium intakes

Supplement use

- There is no information on selenium supplement use in children in Australia or New Zealand

Food supply

- Selenium is permitted to be added to formulated beverages, meal replacements, supplementary sports foods, and foods for special medical purposes (Australian Government 2021, 2025c). There are no regulatory requirements to add selenium to food in Australia or New Zealand (except infant formula).

Selenium exposure in Australia and New Zealand

Special populations

Sex considerations

- There is no evidence that special considerations are needed in relation to sex.
- EFSA's ULs apply to entire age groups for children, they are not differentiated by sex. This is consistent with NHMRCs 2006 ULs.

Benchmarking against comparable international jurisdictions	Meaningful benchmarking against comparable international jurisdictions is not possible for children and adolescents, as no children's ULs are available from the UK Expert Group on Vitamins and Minerals (EVM) or the World Health Organization/Food and Agriculture Organization of the United Nations (WHO/FAO). The only remaining international data for comparison are the USA IOM values (which the 2006 NHMRC values were adopted from) and the 2000 SCF European values, that are superseded by the EFSA 2023 values (upon which the proposed updated UL values are based).	
Balance of effects (benefits and harms)	There is no evidence to suggest that the current ULs for children are not protective of most individuals in the general population of Australia and New Zealand. There is no evidence to suggest that acute or chronic selenosis are a public health concern in Australia or New Zealand.	The adapted ULs for children are expected to be protective of most individuals in the general population of Australia and New Zealand. While there is no evidence that harm from excess consumption of selenium is occurring in Australia or New Zealand with current ULs, there is significant uncertainty around current estimates, which are scaled up from infant data based on breast milk concentration. Although it too requires extrapolation down to children and adolescents, the large RCT identified by EFSA (Lippman et al. 2009) is likely to provide a more reliable estimate of the level at which harm has the potential to occur. The proposed adult UL (330 µg/day). is based on a larger, more recent, higher-quality study (2009 RCT n=8,700 per arm vs 1989 cross-sectional study n=349) that was conducted in a setting more generalisable to the Australian and New Zealand context (USA vs China). The UL for children (extrapolated from adults) will provide additional margin of safety based on more recent higher quality data. Benefits of Adapting EFSA UL • Offers an additional margin of safety through precautionary approach • Provides additional evidence to strengthen supplement regulation and consumer guidance for high-risk consumption patterns **Potential harms/considerations:**

		• May represent a more restrictive approach than currently warranted by the Australian and New Zealand context, where selenium toxicity risk is relatively low due to moderate selenium levels in soil and food supply • May result in more individuals exceeding the UL without signs of harm from excess selenium In Australia there is a relatively low risk of selenium toxicity due to moderate selenium levels in soil and food supply. Certain regions (i.e. central Queensland) have selenium-rich soils. Overall dietary selenium intake remains within safe limits for most of the population There is no evidence to suggest that acute selenosis, chronic selenosis, or alopecia as an early marker of selenosis are a public health concern in Australia or New Zealand. There is no evidence of specific populations that are more sensitive to selenium, at greater risk of excess or more susceptible to the health effects associated with excess consumption. People most likely to develop selenosis are those who consume Brazil nuts or take supplements at levels significantly higher than the UL.
Certainty of the evidence	The evidence underpinning current ULs for children study of selenium breast milk concentration collected from 241 subjects who resided in or near cities located in 17 states across the United States. Although no appraisal of study quality or evidence certainty is available, this evidence is limited by: - The age of the study (conducted in 1975, data is 50 years old) - The small sample size (n=241)	The ULs for children are based on the same evidence as the adult UL. The adult value was extrapolated for children using allometric scaling. Overall, EFSA considered the SELECT trial (Lippman et al. 2009) to be the best available evidence upon which to base their updated UL. *For further information on the certainty of the evidence associated with the SELECT trial, see the Adult Evidence-to-Decision table above.*

Values, preferences and feasibility (consumers, communities)

Modelled selenium intake data demonstrate that average intakes among children and adolescents meet nutritional requirements while remaining well below both current and proposed UL values. As shown in Table 24, most modelled values – based on Foundation Diet modelling - are at or below half of the lowest proposed adapted UL. Despite potential underestimation due to selenium being modelled as an output rather than an input, and incomplete food composition data, the modelled intake patterns are consistent with empirical health data from both Australia and New Zealand (Tables 22 & 23). These findings support the feasibility of implementing a lower UL for children and adolescents without requiring changes to current dietary patterns.

TABLE 24. Comparison of modelled child and adolescent selenium intakes with proposed ULs

Modelled Selenium Intake (Foundation Diet, ug/day)			Comparison with Proposed ULs			
				Proposed ULs (µg/day)		
Age Group	Male	Female	Applicable UL Age Group/s	RETAINED 2006 NHMRC	ADAPTED 2023 EFSA	% Modelled Intake Exceeding UL
13-23 months	38	36	13-23 months	105	85	0%
2 – 3 years	41	39	2-4 years	145	120	0%
4 – 8 years	54	52	2-4/5-11 years	145/220	120/185	0%
9 – 11 years	68	67	5 - 11 years	220	185	0%
12 – 13 years	75	72	12 -17 years	360	295	0%
14 – 18 years	78	82	12 -17 years	360	295	0%
			PROPOSED ADULT ULs	400	330	

Abbreviations: UL, Upper Level

Resource impacts

Basing the revised UL levels for children on updated weights has only minor implications. Additional age groupings are extrapolated from adult values to provide more options for different users to compare against usual intake from national nutrition surveys This minor change

The proposed change to the UL may have implications for regulators, including FSANZ (food and food products) and TGA (supplements). Views will be sought during targeted/stakeholder consultation and considered when developing final NRVs.

	from updated weights should have minimal impact for regulators, including FSANZ (food and food products) and TGA (supplements).	The Australia New Zealand Food Standards Code permits selenium to be added up to a maximum of: • formulated beverage – 17.5 µg/600mL • formulated meal replacements - 17.5 µg/serve inorganic, 9 µg/serve organic • formulated supplementary sports foods - 52 µg/serve inorganic, 26 µg/serve organic • food for special medical purposes represented as a sole source of nutrition - 25µg/MJ At normal levels of consumption these products are unlikely to contribute to exceeding the UL if it is lowered.
Other factors (health equity impacts, sustainability)	The UL should aim to be protective of almost all individuals within the population. Maintaining the current ULs for children should continue to protect the most individuals from the health effects of selenium excess.	The UL should aim to be protective of almost all individuals within the population. Adapting EFSAs ULs and extrapolating for children should continue to protect the most individuals from the health effects of selenium excess.
Decision	*Adapt EFSAs 2023 UL to the Australian and New Zealand context by extrapolating adapted adult values to children using current reference weights.*	

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