Iodine[1]

Iodine (as iodide) is widely but unevenly distributed in the earth's environment. In many regions, leaching from glaciations, flooding, and erosion have depleted surface soils of iodide, and most iodide is found in the oceans. Iodine cycling in many regions is slow and incomplete, leaving soils and drinking water iodine depleted. Iodine deficiency in populations residing in low-iodine areas will persist until iodine enters the food chain through addition of iodine to foods (e.g., iodization of salt) or dietary diversification introduces foods produced outside the iodine-deficient area.

In healthy adults, the absorption of dietary iodine is >90% (1). Iodine is cleared from the circulation mainly by the thyroid and kidney, and although renal iodine clearance is fairly constant, thyroid clearance varies with iodine intake. In iodine-sufficient areas, the adult thyroid traps ~60 μg of iodine/d to balance losses and maintain thyroid hormone synthesis. The body of a healthy adult contains 10 to 20 mg of iodine, of which 70 to 80% is in the thyroid. Iodine is used to build thyroid hormones, which are essential for mammalian life. The thyroid releases thyroid hormone into the circulation, and hormone degradation in the periphery releases iodine that enters the plasma iodine pool and can be taken up by the thyroid or excreted by the kidney. More than 90% of ingested iodine is ultimately excreted in the urine.

Deficiency: Iodine deficiency has multiple adverse effects on growth and development in animals and humans. These are collectively termed the "iodine deficiency disorders" (**Table 1**) and are one of the most important and common human diseases (2). They result from inadequate thyroid hormone production due to lack of sufficient iodine.

The global efforts to control iodine deficiency have been remarkably successful. Although severe endemic goiter has largely disappeared in most parts of the world, mild to moderate iodine deficiency continues to affect 32 countries, more than half of them in the industrialized world (including the United Kingdom and Australia), mainly due to reluctance of the food industry to use iodized salt (3). Ensuring sustainability in countries with successful programs requires regular surveillance and occasional adjustments to the iodine content in salt.

Diet recommendations: Various countries have established nutrient recommendations, including iodine. For the United States and Canada, the Institute of Medicine established Dietary Reference Intakes (DRIs) for iodine, and specifically an Adequate Intake for Infants and an Estimated Average Requirement (EAR) and Recommended Dietary Allowance (RDA) for children, adolescents, and adults (Table 2) (4). The WHO established Recommended Nutrient Intakes (RNIs) that cover the needs of nearly all healthy individuals for a specific life-stage group (**Table 2**) (5).

Food sources: The naturally occurring iodine content of most foods and beverages is low. Foods of marine origin have a higher iodine content because iodine in seawater is concentrated in marine plants and animals. In many countries, use of iodized salt in households during cooking and consumption provides additional iodine.

In the United States, the median intake of iodine from food in 2003–2004 was estimated to be ~20 to 285 μg/d for men and 145 to 200 μg/d for women (6). Major dietary sources of iodine in the United States are dairy products and whole grains (6). There has been concern about the presence of perchlorate in foods and drinking water because perchlorate inhibits the uptake of iodine in the thyroid gland. However, adverse effects in humans at the levels found in food have not been demonstrated.

Clinical uses: Iodine-based disinfectants are commonly used in clinical settings.

Toxicity: As salt iodization spreads across the globe, overiodized salt has contributed to excess iodine intakes in a number of countries and regions, and both iodine deficiency and excess can damage health. European (7) and US (5) expert committees have recommended Tolerable Upper Intake Levels for iodine (**Table 3**), but they caution that

Table 1. Iodine deficiency disorders, by age group

Age group	Health consequences
All ages	Goiter
	Increased susceptibility of the thyroid gland to nuclear radiation
Fetus	Abortion
	Stillbirth
	Congenital anomalies
	Perinatal mortality
Neonate	Infant mortality
	Endemic cretinism
Child and adolescent	Impaired mental function
	Delayed physical development
Adults	Impaired mental function
	Reduced work productivity
	Toxic nodular goiter, iodine-induced hyperthyroidism
	Increased occurrence of hypothyroidism in moderate-to-severe iodine deficiency, decreased occurrence of hypothyroidism in mild-to-moderate iodine deficiency

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Table 2. Recommendations for iodine intake by age or life-stage group[1]

Life-stage group	US Institute of Medicine EAR[2]	US Institute of Medicine AI[3] or RDA[4]	Life-stage group	WHO RNI
	μg/d			*μg/d*
Infants aged 0–12 mo	—	110–130	Children aged 0–5 y	90
Children aged 1–8 y	65	90	Children aged 6–12 y	120
Children aged 9–13 y	73	120		
Adults aged ≥14 y	95	150	Adults aged >12 y	150
Pregnancy	160	220	Pregnancy	250
Lactation	200	290	Lactation	250

[1]AI, Adequate Intake; EAR, Estimated Average Requirement; RDA, Recommended Dietary Allowance; RNI, Recommended Nutrient Intake.
[2]EAR is the average daily nutrient intake level estimated to meet the requirement of half of healthy individuals in a particular life-stage and sex group.
[3]AI is a recommended daily intake level that is expected to meet or exceed the amount to meet the requirement in essentially all individuals of a specific life-stage and sex group.
[4]RDA is the average daily intake level sufficient to meet the requirement of nearly all (97–98%) healthy individuals in a particular life-stage and sex group.

individuals with chronic iodine deficiency may respond adversely to intakes lower than these levels. In monitoring populations who consume iodized salt, the WHO recommendations for the median urinary iodine concentration (UIC) that indicates more-than-adequate and excess iodine intake in school-age children are 200–299 μg/L and >300 μg/L, respectively, and the median UIC that indicates excess iodine intake in pregnant women is >500 μg/L (1).

Recent research: Current activities and future research priorities in the field of iodine nutrition include the following (8):

- Validation/optimization of current UIC cutoffs for vulnerable groups, such as in pregnancy and infancy, using balance studies and functional biomarkers
- Personalization of iodine requirements based on age, sex, ethnicity, environment, and health status
- Development of robust, field-friendly functional biomarkers of thyroid status, including paper-based diagnostics, that respond to varying levels of iodine exposure
- Validation of the extrapolation from the UIC to iodine intakes and application of the EAR cut-point model to allow national programs to derive accurate information on the prevalence of low iodine intakes in the population and to quantify the necessary increase in iodine intakes to ensure sufficiency in the population
- Coordination of public health campaigns to reduce salt intake with iodized salt programs
- Examination of the role of varying iodine intake on the incidence of autoimmune thyroid disease and papillary thyroid cancer
- Iodine and its potential role in the antioxidant and immune response

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Table 3 Tolerable Upper Intake Levels for iodine

Age group[1]	European Commission/Scientific Committee on Food (5)	US Institute of Medicine (4)
	μg/d	
1–3 y	200	200
4–6 y (4–8 y)	250	300
7–10 y (9–13 y)	300	600
11–14 y	450	—
15–17 y (14–18 y)	500	900
Adult	600	1100
Pregnant and lactating women	600	1100

[1]Age categories in parenthesis are for the Tolerable Upper Intake Level defined by US Institute of Medicine (4).

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