Zinc

Sources and Physiological Functions

Zinc is a chemical element that occurs naturally in rocks, soil, water, and at low levels in air. It is one of the more abundant elements in the earth's crust (CRC 2016) and is present in virtually all foods and potable water (WHO 2022). The EPA recommends a maximum zinc concentration in drinking water of 5 mg/L (U.S. Environmental Protection Agency 1979) to prevent water from taking on an undesirable taste (e.g., by zinc leaching into the water from galvanized pipes). Zinc generally enters natural bodies of water through mining and zinc processing for use in manufacturing. Regulations establish limits on the amount of zinc in fertilizers, sewage sludge, and pig and poultry manure to prevent excess zinc in soils that can harm microorganisms and plants (Wolf 2022). Zinc is in many commercial products, including protective coating for other metals (galvanizing), dry cell batteries, and metal alloys like brass and bronze (Wolf 2022). Since 1982, coins in the United States have been made of an alloy of zinc (97.5%) and copper (United States Mint 2022).

The main nonoccupational source of zinc for humans is through diet, including plants and animal products. Oysters, meat, fish, poultry, seafood (e.g., crab and lobster), and fortified cereals are good sources of zinc. Beans, nuts, whole grains, eggs, and dairy products also provide some zinc. Cereals and legumes are the major sources of dietary zinc in developing countries; however, these also contain phytate, which prevents the absorption of zinc unless the food is processed (e.g., through fermentation). So, dietary reliance on cereals and legumes increases the risk of zinc deficiency unless the food is processed or the diet also includes red meat (Wolf 2022). Excess oxalate intake (from spinach, okra, nuts, and tea) is also associated with an acquired form of zinc deficiency (Maxfield 2024). Absorption of zinc through the gastrointestinal tract is homeostatically controlled; under normal conditions, 20%–30% is absorbed (U.S. Agency for Toxic Substances and Disease Registry 2005). Daily intake of iron at levels found in some supplements could decrease zinc absorption. Data suggest that a calcium-rich diet does not have a major effect on zinc absorption at an adequate intake level of calcium. Dietary protein affects zinc absorption because zinc binds to proteins at near neutral pH. Folate bioavailability is enhanced when polyglutamate folate is hydrolyzed by the zinc-dependent enzyme (polyglutamate hydrolase) to the monoglutamate (Institute of Medicine 2001).

Zinc is an essential nutrient that is necessary for the function of many metalloenzymes (Wolf 2022; Maxfield 2024; Institute of Medicine 2001). It helps the human immune system fight off invading bacteria and viruses and make DNA and proteins. During pregnancy, infancy, childhood, and adolescence, zinc helps us grow and develop properly, heal wounds, and have a sense of taste (U.S. National Institutes of Health 2022).

Health Effects

Overt human zinc deficiency is not common in North America (Institute of Medicine 2001). It is common worldwide and happens with greater frequency in developing countries. The WHO has designated zinc deficiency as a major contributing factor to disease globally (Santos 2017; Narváez-Caicedo 2018). Zinc deficiency can be inherited or acquired and can present with growth impairment, sexual dysfunction, infectious, inflammatory, gastrointestinal, or cutaneous involvement (Maxfield 2024).

Excess intake of zinc can also be harmful. Signs include nausea, dizziness, headaches, upset stomach, vomiting, and loss of appetite (U.S. National Institutes of Health 2022). Long-term oral exposure to zinc compounds can cause early symptoms of copper deficiency, such as decreased erythrocytes and hematocrit levels. Copper deficiency happens when the interaction between zinc and copper causes less absorption of dietary copper (U.S. Agency for Toxic Substances and Disease Registry 2024). Very high oral or dermal zinc doses can contribute to copper deficiency and reduce magnesium absorption (U.S. National Institutes of Health 2022).

Intake Recommendations

The Food and Nutrition Board (FNB) at the National Academy of Sciences, Engineering, and Medicine established Adequate Intakes (AIs) and Recommended Dietary Allowances (RDAs) for zinc. AIs and RDAs depend on an individual's life stage and sex group (Institute of Medicine 2001). The FNB also recommends a specific average amount of zinc that individuals should consume every day. RDAs are the average daily amount of zinc needed to meet the nutrient requirement of nearly all (97–98%) healthy individuals. AIs are used when an RDA cannot be determined—they are based on observations and experiments that estimate nutrient intake. The AI for zinc for infants is 2.0 mg/day (0–6 months). The RDAs for zinc are as follows:

- 3 mg/day (7–12 months)
- 3 mg/day (1–3 years)

- 5 mg/day (4–8 years)
- 8 mg/day (9–13 years)
- 11 mg/day (boys 14–18 years)
- 9 mg/day (girls 14–18 years)
- 11 mg/day (men ≥19 years)
- 8 mg/day (women ≥19 years)

The RDAs for zinc for pregnancy are 12 mg/day (14–18 years) and 11 mg/day (≥19 years). For lactation, the RDAs are 13 mg/day (14–18 years) and 12 mg/day (≥19 years).

Vegetarians may require as much as 50% more dietary zinc, especially strict vegetarians whose major food staples are grains and legumes and whose dietary phytate:zinc molar ratio exceeds 15:1. The daily requirements for dietary zinc are also greater for those who consume alcohol on a long-term basis, which is associated with impaired zinc absorption and increased urinary zinc excretion. Approximately 30%–50% of alcoholics have low zinc status.

The FNB also established a Tolerable Upper Intake Level (UL), which is the highest level of daily nutrient intake that is likely to pose no risk of adverse health effects for almost all individuals (Institute of Medicine 2001). These are the ULs for zinc:

- 4 mg/day (0–6 months)
- 5 mg/day (7–12 months)
- 7 mg/day (1–3 years)
- 12 mg/day (4–8 years)
- 23 mg/day (9–13 years)
- 34 mg/day (14–18 years, including pregnancy and lactation)
- 40 mg/day (≥19 years, including pregnancy and lactation)

Individuals with Menkes disease may be distinctly susceptible to the adverse effects of excess zinc intake. The UL is not meant to apply to individuals who are being treated with zinc under close medical supervision.

The WHO Guidelines for Drinking Water Quality note that zinc is not a health concern at levels typically found in drinking water (WHO 2022). The report also says that zinc gives an undesirable astringent taste to water at a taste threshold concentration of about 4 mg/L (as zinc sulfate). It also notes that water containing zinc at concentrations more than 3–5 mg/L may appear opalescent and

develop a greasy film on boiling. Similarly, the EPA's Secondary Drinking Water Standards Guidance for Nuisance Chemicals (U.S. Environmental Protection Agency 1979) recommends a level of less than 5 mg/L in drinking water.

Biochemical Indicators

Serum zinc is the established biomarker to assess zinc exposure (U.S. Agency for Toxic Substances and Disease Registry 2005; Martinez-Morata 2023), though it is reported to vary with infections, sex, age, time of day, and physical conditions such as pregnancy (Andrew 2023).

Analytical Methods

Serum zinc is often measured using highly specific inductively coupled plasma mass spectrometry (ICP-MS) or by atomic absorption spectrometry (AAS). A standard reference material (SRM 1598a Inorganic constituents in animal serum) is available from the National Institute of Standards and Technology (NIST) with certified values for zinc. The New York State Department of Health's Wadsworth Center, College of American Pathologists, and Center for Toxicology in Quebec offer external quality assessment or proficiency testing programs for metals in biological matrices, which include zinc in serum.

Findings from NHANES

The National Health and Nutrition Examination Survey (NHANES) is the only source for nationally representative data on serum zinc for the U.S. population (Pfeiffer 2026). Serum zinc data were collected in the U.S. population for participants ages 3 years and older from NHANES II (1976–1980) by atomic absorption spectrometry (AAS). Serum zinc was measured in the U.S. population for participants ages 6 years and older from NHANES 2011–2016 (from a 1/3 sample subset) and was generated by inductively coupled plasma mass spectrometry (ICP-MS). Using serum zinc concentrations measured in NHANES 2011–2016, researchers determined recommended reference intervals that could be transferred for routine use in other clinical biochemistry

laboratories (Andrew 2023). The mean and median serum zinc concentrations for supplement nonusers across these cycles were 80.5–81.9 µg/dL and 80.8–82.5 µg/dL. For supplement users, the mean and median concentrations were 79.2–81.9 µg/dL and 80.1–81.0 µg/dL. Serum zinc concentrations were affected by gender, age, fasting, ethnicity, serum albumin concentration, health status (in males), time of venipuncture, and pregnancy. The reference interval concentrations for all demographics were above the nutritional cutoff point of 6.9 µmol/L (45 µg/dL) proposed in the literature.

For more information about zinc, see the Institute of Medicine's Dietary Reference Intake report (Institute of Medicine 2001), and fact sheets from the National Institutes of Health, Office of Dietary Supplements (https://ods.od.nih.gov/factsheets/list-VitaminsMinerals/).

Data in the 2026 tables

Data presented are from univariate analysis that was not adjusted for demographic variables (e.g., age, sex, race and Hispanic origin) or other blood concentration determinants (e.g., dietary intake, supplement use, smoking, BMI). Data for serum zinc were available from three NHANES cycles between 2011 and 2016 for persons ages 6 years and older from a 1/3 subsample. The same inductively coupled plasma mass spectrometry (ICP-MS) method has been used throughout.

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