Dietary Supplement Fact Sheet: Selenium

Office of Dietary Supplements • NIH Clinical Center • National Institutes of Health

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What is selenium?

Selenium is a trace mineral that is essential to good health but required only in small amounts [1,2]. Selenium is incorporated into proteins to make selenoproteins, which are important antioxidant enzymes. The antioxidant properties of selenoproteins help prevent cellular damage from free radicals. Free radicals are natural by-products of oxygen metabolism that may contribute to the development of chronic diseases such as cancer and heart disease [2,3]. Other selenoproteins help regulate thyroid function and play a role in the immune system [4-7].

What foods provide selenium?

Plant foods are the major dietary sources of selenium in most countries throughout the world. The content of selenium in food depends on the selenium content of the soil where plants are grown or animals are raised. For example, researchers know that soils in the high plains of northern Nebraska and the Dakotas have very high levels of selenium. People living in those regions generally have the highest selenium intakes in the United States (U.S.) [8]. In the U.S., food distribution patterns across the country help prevent people living in low-selenium geographic areas from having low dietary selenium intakes. Soils in some parts of China and Russia have very low amounts of selenium. Selenium deficiency is often reported in those regions because most food in those areas is grown and eaten locally.

Selenium also can be found in some meats and seafood. Animals that eat grains or plants that were grown in selenium-rich soil have higher levels of selenium in their muscle. In the U.S., meats and bread are common sources of dietary selenium [9,10]. Some nuts are also sources of selenium.

Selenium content of foods can vary. For example, Brazil nuts may contain as much as 544 micrograms of selenium per ounce. They also may contain far less selenium. It is wise to eat Brazil nuts only occasionally because of their unusually high intake of selenium. Selected food sources of selenium are provided in Table 1 [11].

Table 1: Selected food sources of selenium [11]

Food	Micrograms (µg)	Percent DV*
Brazil nuts, dried, unblanched, 1 ounce	544	780
Tuna, light, canned in oil, drained, 3 ounces	63	95
Beef, cooked, 3½ ounces	35	50

Spaghetti w/ meat sauce, frozen entrée, 1 serving	34	50
Cod, cooked, 3 ounces	32	45
Turkey, light meat, roasted, 3½ ounces	32	45
Beef chuck roast, lean only, roasted, 3 ounces	23	35
Chicken Breast, meat only, roasted, 3½ ounces	20	30
Noodles, enriched, boiled, 1/2 cup	17	25
Macaroni, elbow, enriched, boiled, 1/2 cup	15	20
Egg, whole, 1 medium	14	20
Cottage cheese, low fat 2%, 1/2 cup	12	15
Oatmeal, instant, fortified, cooked, 1 cup	12	15
Rice, white, enriched, long grain, cooked, 1/2 cup	12	15
Rice, brown, long-grained, cooked, 1/2 cup	10	15
Bread, enriched, whole wheat, commercially prepared, 1 slice	10	15
Walnuts, black, dried, 1 ounce	5	8
Bread, enriched, white, commercially prepared, 1 slice	4	6
Cheddar cheese, 1 ounce	4	6

*DV = Daily Value. DVs are reference numbers developed by the Food and Drug Administration (FDA) to help consumers determine if a food contains a lot or a little of a specific nutrient. The DV for selenium is 70 micrograms (ug). Most food labels do not list a food's selenium content. The percent DV (%DV) listed on the table indicates the percentage of the DV provided in one serving. A food providing 5% of the DV or less is a low source while a food that provides 10-19% of the DV is a good source. A food that provides 20% or more of the DV is high in that nutrient. It is important to remember that foods that provide lower percentages of the DV also contribute to a healthful diet. For foods not listed in this table, please refer to the U.S. Department of Agriculture's Nutrient Database Web site: http://www.nal.usda.gov/fnic/cgi-bin/nut_search.pl.

What is the recommended dietary intake for selenium?

Recommendations for selenium are provided in the Dietary Reference Intakes developed by the Institute of Medicine [12]. *Dietary Reference Intakes* (DRIs) is the general term for a set of reference values used for planning and assessing nutrient intake for healthy people. Three important types of reference values included in the DRIs are *Recommended Dietary Allowances* (RDA), *Adequate Intakes* (AI), and *Tolerable Upper Intake Levels* (UL). The RDA recommends the average daily dietary intake level that is sufficient to meet the nutrient requirements of nearly all (97-98%) healthy individuals in each age and gender group [12]. An AI is set when there is insufficient scientific data available to establish a RDA. AIs meet or exceed the amount needed to maintain a nutritional state of adequacy in nearly all members of a specific age and gender group. The UL, on the other hand, is the maximum daily intake unlikely to result in adverse health effects [12]. Table 2 lists the RDAs for selenium, in micrograms (µg) per day, for children and adults.

Table 2: Recommended Dietary Allowances (RDA) for selenium for children and adults [12]

Age (years)	Males and Females (µg/day)	Pregnancy (µg/day)	Lactation (µg/day)
1-3 y	20	N/A	N/A
4-8 y	30	N/A	N/A
9-13 y	40	N/A	N/A
14-18 y	55	60	70
19 y +	55	60	70

There is insufficient information on selenium to establish a RDA for infants. An Adequate Intake (AI) has been established that is based on the amount of selenium consumed by healthy

infants who are fed breast milk [12]. Table 3 lists the AIs for selenium, in micrograms (μg) per day, for infants.

Table 2: Adequate Intake for selenium for infants [12]

Age (months)	Males and Females (μg/day)
0-6 months	15
7-12 months	20

Results of the National Health and Nutrition Examination Survey (NHANES III-1988-94) indicated that diets of most Americans provide recommended amounts of selenium [13]. The INTERMAP study examined nutrient intakes of almost 5,000 middle-aged men and women in four countries in the late 1990s, including the U.S. The primary aim of the study was to evaluate the effect of dietary micronutrients on blood pressure. Each study participant completed four, 24-hour dietary recalls, during which they were asked to record everything consumed (food, beverages, and dietary supplements) over the previous 24 hours. Selenium intake was lowest among residents of China, the country with the highest known rate of selenium deficiency. Mean dietary intake of selenium of U.S. participants was 153 μg for men and 109 μg for women. Both values exceed the recommended selenium intake for adults and are further evidence of adequate selenium intakes in the U.S. [14].

When can selenium deficiency occur?

Human selenium deficiency is rare in the U.S. but is seen in other countries, most notably China, where soil concentration of selenium is low [15]. There is evidence that selenium deficiency may contribute to development of a form of heart disease, hypothyroidism, and a weakened immune system [16,17]. There is also evidence that selenium deficiency does not usually cause illness by itself. Rather, it can make the body more susceptible to illnesses caused by other nutritional, biochemical or infectious stresses [18].

Three specific diseases have been associated with selenium deficiency:
- Keshan Disease, which results in an enlarged heart and poor heart function, occurs in selenium deficient children.
- Kashin-Beck Disease, which results in osteoarthropathy
- Myxedematous Endemic Cretinism, which results in mental retardation

Keshan disease was first described in the early 1930s in China, and is still seen in large areas of the Chinese countryside with selenium poor soil [18]. Dietary intake in these areas is less than 19 micrograms per day for men and less than 13 micrograms per day for women, significantly lower than the current RDA for selenium [12]. Researchers believe that selenium deficient people infected with a specific virus are most likely to develop Keshan disease [18,19].

Selenium deficiency has also been seen in people who rely on total parenteral nutrition (TPN) as their sole source of nutrition [20,21]. TPN is a method of feeding nutrients through an intravenous (IV) line to people whose digestive systems do not function. Forms of nutrients that do not require digestion are dissolved in liquid and infused through the IV line. It is important for TPN solutions to provide selenium in order to prevent a deficiency [22]. Physicians can monitor the selenium status of individuals receiving TPN to make sure they are receiving adequate amounts.

Severe gastrointestinal disorders may decrease the absorption of selenium, resulting in selenium depletion or deficiency [23]. Gastrointestinal problems that impair selenium absorption usually affect absorption of other nutrients as well, and require routine monitoring of nutritional status so that appropriate medical and nutritional treatment can be provided.

Who may need supplemental selenium?

In the U.S., most cases of selenium depletion or deficiency are associated with severe gastrointestinal problems, such as Crohn's disease, or with surgical removal of part of the

stomach. These and other gastrointestinal disorders can impair selenium absorption [24-26]. People with acute severe illness who develop inflammation and widespread infection often have decreased levels of selenium in their blood [27]. Physicians will evaluate individuals who have gastrointestinal disease or severe infection for depleted blood levels of selenium to determine the need for supplementation.

People with iodine deficiency may also benefit from selenium supplementation. Iodine deficiency is rare in the U.S., but is still common in developing countries where access to iodine is limited [28]. Researchers believe that selenium deficiency may worsen the effects of iodine deficiency on thyroid function, and that adequate selenium nutritional status may help protect against some of the neurological effects of iodine deficiency [6,7]. Researchers involved in the Supplementation en Vitamines et Mineraux AntioXydants (SU.VI.MAX) study in France, which was designed to assess the effect of vitamin and mineral supplements on chronic disease risk, evaluated the relationship between goiter and selenium in a subset of this research population. Their findings suggest that selenium supplements may be protective against goiter, which refers to enlargement of the thyroid gland [29].

As noted above, selenium supplementation during TPN administration is now routine [21,22]. While specific medical problems such as those described above indicate a need for selenium supplementation, evidence is lacking for recommending selenium supplements for healthy children and adults.

Selenium supplements
Selenium occurs in staple foods such as corn, wheat, and soybean as selenomethionine, the organic selenium analogue of the amino acid methionine [30,31]. Selenomethionine can be incorporated into body proteins in place of methionine, and serves as a vehicle for selenium storage in organs and tissues. Selenium supplements may also contain sodium selenite and sodium selenate, two inorganic forms of selenium. Selenomethionine is generally considered to be the best absorbed and utilized form of selenium.

Selenium is also available in 'high selenium yeasts', which may contain as much as 1,000 to 2,000 micrograms of selenium per gram [30]. Most of the selenium in these yeasts is in the form of selenomethionine. This form of selenium was used in the large scale cancer prevention trial in 1983, which demonstrated that taking a daily supplement containing 200 micrograms of selenium per day could lower the risk of developing prostate, lung, and colorectal cancer [32]. However, some yeasts may contain inorganic forms of selenium, which are not utilized as well as selenomethionine.

A study conducted in 1995 suggested that the organic forms of selenium increased blood selenium concentration to a greater extent than inorganic forms. However, it did not significantly improve the activity of the selenium-dependent enzyme, glutathione peroxidase [33]. Researchers are continuing to examine the effects of different chemical forms of selenium, but the organic form currently appears to be the best choice.

What are some current issues and controversies about selenium?

Selenium and cancer
Observational studies indicate that death from cancer, including lung, colorectal, and prostate cancers, is lower among people with higher blood levels or intake of selenium [34-40]. In addition, the incidence of nonmelanoma skin cancer is significantly higher in areas of the United States with low soil selenium content [37]. The effect of selenium supplementation on the recurrence of different types of skin cancers was studied in seven dermatology clinics in the U.S. from 1983 through the early 1990s. Taking a daily supplement containing 200 μg of selenium did not affect recurrence of skin cancer, but significantly reduced the occurrence and death from total cancers. The incidence of prostate cancer, colorectal cancer, and lung cancer was notably lower in the group given selenium supplements [41].

Research suggests that selenium affects cancer risk in two ways. As an anti-oxidant, selenium can help protect the body from damaging effects of free radicals. Selenium may also prevent or slow tumor growth. Certain breakdown products of selenium are believed to prevent tumor growth by enhancing immune cell activity and suppressing development of blood vessels to the tumor [42].

However, not all studies have shown a relationship between selenium status and cancer. In 1982, over 60,000 participants of the Nurse's Health Study with no history of cancer submitted toenail clippings for selenium analysis. Toenails are thought to reflect selenium status over the previous year. After three and a half years of data collection, researchers compared toenail selenium levels of nurses with and without cancer. Those nurses with higher levels of selenium in their toenails did not have a reduced risk of cancer [43].

Two important long-term studies, the SU.VI.MAX study in France and the Selenium and Vitamin E Cancer Prevention Trial (SELECT) study in the U.S., are now underway to further investigate the selenium/cancer prevention link.

The SU.VI.MAX Study is a prevention trial looking at the effects of antioxidant vitamins and minerals on chronic diseases such as cancer and cardiovascular disease. Doses of the nutrients provided in the study are one to three times higher than recommended intakes, including a daily supplement of 100 μg selenium. The SU.VI.MAX study, which began in 1994, has followed more than 12,000 adult men and women. This study was designed to continue for eight years, and the research community is eagerly awaiting the results of this study [44].

The SELECT study, a long-term study sponsored by the NIH, is investigating whether supplemental selenium and/or vitamin E can decrease the risk of prostate cancer in healthy men. Past evidence as well as pre-clinical trials for the SELECT study suggests that these two nutrients may be effective in preventing prostate cancer. A daily supplement containing 200 μg of selenium will be given to individuals in the selenium-only study group, while men in the combined-nutrients group will receive a daily supplement containing 200 μg selenium and 400 mg vitamin E. The study, which will span from 2001 to 2013, will include 32,400 healthy adult men [45].

Selenium and heart disease
Some population surveys have suggested an association between lower antioxidant intake and a greater incidence of heart disease [46]. Evidence also suggests that oxidative stress from free radicals, which are natural by-products of oxygen metabolism, may promote heart disease [47-49]. For example, it is the oxidized form of low-density lipoproteins (LDL, often called "bad" cholesterol) that promotes plaque build-up in coronary arteries [48]. Selenium is one of a group of antioxidants that may help limit the oxidation of LDL cholesterol and thereby help to prevent coronary artery disease [47-49]. Currently there is insufficient evidence available to recommend selenium supplements for the prevention of coronary heart disease; however, the SU.VI.MAX study mentioned earlier is looking at the effects of antioxidant nutrients such as selenium on heart disease.

Selenium and arthritis
Surveys indicate that individuals with rheumatoid arthritis, a chronic disease that causes pain, stiffness, swelling, and loss of function in joints, have reduced selenium levels in their blood [50-51]. In addition, some individuals with arthritis have a low selenium intake [52].

The body's immune system naturally makes free radicals that can help destroy invading organisms and damaged tissue, but that can also harm healthy tissue [53]. Selenium, as an antioxidant, may help to relieve symptoms of arthritis by controlling levels of free radicals [54]. Current findings are considered preliminary, and further research is needed before selenium supplements can be recommended for individuals with arthritis.

Selenium and HIV
HIV/AIDS malabsorption can deplete levels of many nutrients, including selenium. Selenium deficiency is associated with decreased immune cell counts, increased disease progression, and high risk of death in the HIV/AIDS population [55,56]. HIV/AIDS gradually destroys the immune system, and oxidative stress may contribute to further damage of immune cells. Antioxidant nutrients such as selenium help protect cells from oxidative stress, thus potentially slowing progression of the disease [57]. Selenium also may be needed for the replication of the HIV virus, which could further deplete levels of selenium [58].

An examination of 125 HIV-positive men and women linked selenium deficiency with a higher rate of death from HIV [59]. In a small study of 24 children with HIV who were observed for five years, those with low selenium levels died at a younger age, which may indicate faster disease progression [60]. Results of research studies have led experts to suggest that selenium

status may be a significant predictor of survival for those infected with HIV [61].

Researchers continue to investigate the relationship between selenium and HIV/AIDS, including the effect of selenium levels on disease progression and mortality. There is insufficient evidence to routinely recommend selenium supplements for individuals with HIV/AIDS, but physicians may prescribe such supplements as part of an overall treatment plan. It is also important for HIV-positive individuals to consume recommended amounts of selenium in their diet.

What is the health risk of too much selenium?

High blood levels of selenium (greater than 100 μg/dL) can result in a condition called selenosis [62]. Symptoms of selenosis include gastrointestinal upsets, hair loss, white blotchy nails, garlic breath odor, fatigue, irritability, and mild nerve damage [2].

Selenium toxicity is rare in the U.S. The few reported cases have been associated with industrial accidents and a manufacturing error that led to an excessively high dose of selenium in a supplement [63,64]. The Institute of Medicine of the National Academy of Sciences has set a tolerable upper intake level (UL) for selenium at 400 micrograms per day for adults to prevent the risk of developing selenosis [12]. Table 4 lists ULs for selenium, in micrograms per day, for infants, children, and adults.

Table 4: Tolerable Upper Intake Levels for selenium for infants, children, and adults [12]

Age	Males and Females (μg/day)
0 - 6 months	45
7 - 12 months	60
1-3 y	90
4-8 y	150
9-13 y	280
14-18 y	400
19 y +	400

Selecting a healthful diet

The 2000 *Dietary Guidelines for Americans* states, "Different foods contain different nutrients and other healthful substances. No single food can supply all the nutrients in the amounts you need" [65]. For more information about building a healthful diet, refer to the *Dietary Guidelines for Americans* [65] http://www.usda.gov/cnpp/DietGd.pdf and the Food Guide Pyramid [66] http://www.nal.usda.gov/fnic/Fpyr/pyramid.html.

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The NIH Clinical Center is the clinical research hospital for NIH. Through clinical research, physicians and scientist translate laboratory discoveries into better treatments, therpaies and interventions to improve the nation's health.

General Safety Advisory

Health professionals and consumers need credible information to make thoughtful decisions about eating a healthful diet and using vitamin and mineral supplements. To help guide those decisions, registered dietitians at the NIH Clinical Center developed a series of Fact Sheets in conjunction with ODS. These Fact Sheets provide responsible information about the role of vitamins and minerals in health and disease. Each Fact Sheet in this series received extensive review by recognized experts from the academic and research communities.

The information is not intended to be a substitute for professional medical advice. It is important to seek the advice of a physician about any medical condition or symptom. It is also important to seek the advice of a physician, registered dietitian, pharmacist, or other qualified health professional about the appropriateness of taking dietary supplements and their potential interactions with medications.

Reviewers

The Clinical Nutrition Service and the ODS thank the expert scientific reviewers for their role in ensuring the scientific accuracy of the information discussed in these fact sheets, along with the Nutrition Education Subcommittee of the NIH, the U.S. Department of Agriculture Dietary Guidance Working Group, and the Department of Health and Human Services Nutrition Policy Board Committee on Dietary Guidance. Reviewers:
Jed Fahey, M.S., Johns Hopkins School of Medicine
Marianna Fordyce-Baum, Ph.D., University of Miami School of Medicine
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