**Vitamin A and Carotenoids**

This is a fact sheet intended for health professionals. For a general overview of Vitamin A and Carotenoids, see our [consumer fact sheet on Vitamin A and Carotenoids](https://ods.od.nih.gov/factsheets/VitaminA-Consumer/).

## Introduction

Vitamin A is the name of a group of fat-soluble retinoids, primarily retinol and retinyl esters [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1),[2](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en2)]. Vitamin A is involved in immune function, cellular communication, growth and development, and male and female reproduction [[1-3](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1)]. Vitamin A supports cell growth and differentiation, playing a critical role in the normal formation and maintenance of the heart, lungs, eyes, and other organs [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1),[2](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en2)]. Vitamin A is also critical for vision as an essential component of rhodopsin, the light-sensitive protein in the retina that responds to light entering the eye, and because it supports the normal differentiation and functioning of the conjunctival membranes and cornea [[2](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en2),[4](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en4)].

The human diet contains two sources for vitamin A: preformed vitamin A (retinol and retinyl esters) and provitamin A carotenoids [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1),[5](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en5)]. Preformed vitamin A is found in foods from animal sources, including dairy products, eggs, fish, and organ meats [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1),[2](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en2)]. Provitamin A carotenoids are plant pigments that the body converts into vitamin A in the intestine [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1),[3](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en3)]. The main provitamin A carotenoids in the human diet are beta-carotene, alpha-carotene, and beta-cryptoxanthin [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1)]. Other carotenoids in food, such as lycopene, lutein, and zeaxanthin, are not converted into vitamin A and are referred to as non-provitamin A carotenoids; they might have other important activities not involving vitamin A formation [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1)].

The various forms of vitamin A are solubilized into micelles in the intestinal lumen and absorbed by duodenal mucosal cells [[5](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en5)]. Retinyl esters and provitamin A carotenoids are converted to retinol after uptake into the lumen (for retinyl esters) or absorption (for provitamin A carotenoids). Retinol is then oxidized to retinal and retinoic acid, the two main active vitamin A metabolites in the body [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1)]. Most of the body’s vitamin A is stored in the liver in the form of retinyl esters [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1)].

Retinol and carotenoid levels are typically measured in plasma or serum because blood samples are easy to collect [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1)]. However, these levels are not always reliable indicators of vitamin A status because they do not decline until vitamin A levels in the liver and other storage sites are almost depleted and because acute and chronic infections can decrease serum and plasma retinol concentrations [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1)]. Most vitamin A is stored in the liver, so measuring vitamin A levels in the liver is the best way to assess vitamin A adequacy [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1)]. In clinical studies, specialized research laboratories can measure liver vitamin A reserves indirectly using isotope-dilution or dose-response methods, in which plasma levels of retinol, a tracer surrogate, or both are measured over several days after the administration of vitamin A [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1)].

In clinical practice, plasma retinol levels alone can be used to document significant deficiency. A serum or plasma retinol concentration of 20 mcg/dL (0.70 micromoles/L) or less frequently reflects moderate vitamin A deficiency, and a level of 10 mcg/dL (0.35 micromoles/L) or less is considered an indicator of severe vitamin A deficiency [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1)].

## Recommended Intakes

Intake recommendations for vitamin A and other nutrients are provided in the Dietary Reference Intakes (DRIs) developed by the Food and Nutrition Board (FNB) at the National Academies of Sciences, Engineering, and Medicine [[5](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en5)]. DRI is the general term for a set of reference values used for planning and assessing nutrient intakes of healthy people. These values, which vary by age and sex, include the following:

* Recommended Dietary Allowance (RDA): Average daily level of intake sufficient to meet the nutrient requirements of nearly all (97%–98%) healthy individuals; often used to plan nutritionally adequate diets for individuals
* Adequate Intake (AI): Intake at this level is assumed to ensure nutritional adequacy; established when evidence is insufficient to develop an RDA
* Estimated Average Requirement (EAR): Average daily level of intake estimated to meet the requirements of 50% of healthy individuals; usually used to assess the nutrient intakes of groups of people and to plan nutritionally adequate diets for them; can also be used to assess the nutrient intakes of individuals
* Tolerable Upper Intake Level (UL): Maximum daily intake unlikely to cause adverse health effects

RDAs for vitamin A are given as retinol activity equivalents (RAE) to account for the different bioactivities of retinol and provitamin A carotenoids, all of which are converted by the body into retinol (see Table 1). One mcg RAE is equivalent to 1 mcg retinol, 2 mcg supplemental beta-carotene, 12 mcg dietary beta-carotene, or 24 mcg dietary alpha-carotene or beta-cryptoxanthin [[5](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en5)].

| **Table 1: Recommended Dietary Allowances (RDAs) for Vitamin A [**[**5**](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en5)**]** | | | | |
| --- | --- | --- | --- | --- |
| **Age** | **Male** | **Female** | **Pregnancy** | **Lactation** |
| Birth to 6 months\* | 400 mcg RAE | 400 mcg RAE |  |  |
| 7–12 months\* | 500 mcg RAE | 500 mcg RAE |  |  |
| 1–3 years | 300 mcg RAE | 300 mcg RAE |  |  |
| 4–8 years | 400 mcg RAE | 400 mcg RAE |  |  |
| 9–13 years | 600 mcg RAE | 600 mcg RAE |  |  |
| 14–18 years | 900 mcg RAE | 700 mcg RAE | 750 mcg RAE | 1,200 mcg RAE |
| 19–50 years | 900 mcg RAE | 700 mcg RAE | 770 mcg RAE | 1,300 mcg RAE |
| 51+ years | 900 mcg RAE | 700 mcg RAE |  |  |

\*AI, equivalent to the mean intake of vitamin A in healthy, breastfed infants.

The units of measurement for vitamin A are now mcg RAE, but International Units (IUs) were previously used [[6](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en6)]. To convert IU to mcg RAE, use the following [[7-9](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en7)]:

* 1 IU retinol = 0.3 mcg RAE
* 1 IU supplemental beta-carotene = 0.3 mcg RAE
* 1 IU dietary beta-carotene = 0.05 mcg RAE
* 1 IU dietary alpha-carotene or beta-cryptoxanthin = 0.025 mcg RAE

RAE can only be directly converted into IUs if the sources of vitamin A are known. For example, the RDA of 900 mcg RAE for adolescent and adult men is equivalent to 3,000 IU if the food or supplement source is preformed vitamin A (retinol) or if the supplement source is beta-carotene. This RDA is also equivalent to 18,000 IU beta-carotene from food or to 36,000 IU alpha-carotene or beta-cryptoxanthin from food. Therefore, a mixed diet containing 900 mcg RAE provides between 3,000 and 36,000 IU vitamin A, depending on the foods consumed.

## Sources of Vitamin A

### Food

Concentrations of preformed vitamin A are highest in liver, fish, eggs, and dairy products [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1)]. Most dietary provitamin A in the U.S. diet comes from leafy green vegetables, orange and yellow vegetables, tomato products, fruits, and some vegetable oils [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1),[5](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en5),[10](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en10)]. Vitamin A is routinely added to some foods, including milk and margarine [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1),[2](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en2)]. Some ready-to-eat cereals are also fortified with vitamin A.

About 65% to 80% of vitamin A consumed in the United States and other high-income countries comes from preformed vitamin A, whereas provitamin A is the main form consumed in low-income countries, where diets include more plant-based foods [[2](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en2),[11](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en11)]. Among U.S. children and adolescents, enriched and fortified foods account for 34%–40% of vitamin A intakes from food [[12](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en12)].

The body might absorb up to 75% to 100% of retinol and, in most cases, 10% to 30% of beta-carotene from foods [[13](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en13),[14](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en14)]. Cooking and heat treatment can increase the bioavailability of beta-carotene from foods [[15](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en15)].

Table 2 lists a variety of foods and their vitamin A content per serving. The foods from animal sources in Table 2 contain primarily preformed vitamin A, the plant-based foods have provitamin A, and the foods with a mixture of ingredients from animals and plants contain both preformed vitamin A and provitamin A.

| **Table 2: Vitamin A Content of Selected Foods [**[**16**](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en16)**]** | | |
| --- | --- | --- |
| **Food** | **microgram (mcg) RAE per serving** | **Percent DV\*** |
| Beef liver, pan fried, 3 ounces | 6,582 | 731 |
| Sweet potato, baked in skin, 1 whole | 1,403 | 156 |
| Spinach, frozen, boiled, ½ cup | 573 | 64 |
| Pumpkin pie, commercially prepared, 1 piece | 488 | 54 |
| Carrots, raw, ½ cup | 459 | 51 |
| Herring, Atlantic, pickled, 3 ounces | 219 | 24 |
| Ice cream, French vanilla, soft serve, ⅔ cup | 185 | 21 |
| Milk, skim, with added vitamin A and vitamin D, 1 cup | 149 | 17 |
| Cantaloupe, raw, ½ cup | 135 | 15 |
| Cheese, ricotta, part skim, ½ cup | 133 | 15 |
| Peppers, sweet, red, raw, ½ cup | 117 | 13 |
| Mangos, raw, 1 whole | 112 | 12 |
| Breakfast cereals, fortified with 10% of the DV for vitamin A, 1 serving | 90 | 10 |
| Egg, hard boiled, 1 large | 75 | 8 |
| Black-eyed peas (cowpeas), boiled, 1 cup | 66 | 7 |
| Apricots, dried, sulfured, 5 apricots | 63 | 7 |
| Broccoli, boiled, ½ cup | 60 | 7 |
| Salmon, sockeye, cooked, 3 ounces | 59 | 7 |
| Tomato juice, canned, ¾ cup | 42 | 5 |
| Yogurt, plain, low fat, 1 cup | 32 | 4 |
| Tuna, light, canned in oil, drained, 3 ounces | 20 | 2 |
| Baked beans, canned, plain or vegetarian, 1 cup | 13 | 1 |
| Summer squash, all varieties, boiled, ½ cup | 10 | 1 |
| Chicken, breast meat and skin, roasted, ½ breast | 5 | 1 |
| Pistachio nuts, dry roasted, 1 ounce | 4 | 0 |

\*DV = Daily Value. Food and Drug Administration (FDA) developed DVs to help consumers compare the nutrient contents of foods and dietary supplements within the context of a total diet. The DV for vitamin A is 900 mcg RAE for adults and children age 4 years and older [[7](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en7)], where 1 mcg RAE = 1 mcg retinol, 2 mcg beta-carotene from supplements, 12 mcg beta-carotene from foods, 24 mcg alpha-carotene, or 24 mcg beta-cryptoxanthin. FDA does not require food labels to list vitamin A content unless vitamin A has been added to the food. Foods providing 20% or more of the DV are considered to be high sources of a nutrient, but foods providing lower percentages of the DV also contribute to a healthful diet.

The U.S. Department of Agriculture’s (USDA’s) [FoodData Central](https://fdc.nal.usda.gov/)[external link disclaimer](https://ods.od.nih.gov/About/exit_disclaimer.aspx) lists the nutrient content of many foods and provides a comprehensive list of foods containing vitamin A arranged by [nutrient content](https://ods.od.nih.gov/pubs/usdandb/VitaminA-Content.pdf) and by [food name](https://ods.od.nih.gov/pubs/usdandb/VitaminA-Food.pdf).

### Dietary supplements

Vitamin A is available in stand-alone supplements and most multivitamins, often in the form of retinyl acetate, retinyl palmitate, provitamin A beta-carotene, or a combination [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1),[17](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en17)]. Amounts of vitamin A in supplements vary widely, but 3,000 mcg RAE (333% of the DV) is common [[17](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en17)]. Multivitamins commonly have somewhat lower amounts, often 750 to 1,050 mcg RAE (83% to 117% of the DV).

The absorption of preformed vitamin A esters from dietary supplements is 70%–90%, and that of beta-carotene ranges from 8.7% to 65% [[15](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en15),[18](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en18)].

## Vitamin A Intakes and Status

Average daily intakes of vitamin A from foods and beverages in the United States were 682 mcg RAE for men age 20 and older and 616 mcg RAE for women in 2017–2018, according to the National Health and Nutrition Examination Survey (NHANES) [[19](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en19)]. For children age 2–19, mean daily intakes of vitamin A from foods and beverages ranged from 497 to 680 mcg RAE. An analysis of biochemical data from 2003–2006 NHANES data indicates that less than 1% of the U.S. population has a serum retinol level of less than 20 mcg/dL, which indicates that vitamin A deficiency is uncommon in the U.S. population [[20](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en20)].

Data from NHANES III, conducted from 1988 to 1994, showed that approximately 26% of the vitamin A in RAEs consumed by men and 34% of that consumed by women in the United States comes from provitamin A carotenoids [[5](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en5)]. The remainder comes from preformed vitamin A, mostly in the form of retinyl esters.

About 12% to 40% of the U.S. population, depending on age, uses supplements containing vitamin A [[21](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en21)]. Adults age 71 years or older and children younger than 9 are more likely than members of other age groups to take supplements containing vitamin A.

## Vitamin A Deficiency

Frank vitamin A deficiency is rare in the United States. However, vitamin A deficiency is still common in many developing countries, often as a result of limited access to foods containing preformed vitamin A from animal-based food sources and to foods containing provitamin A carotenoids because of poverty or traditional diets [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1),[22](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en22)]. A pooled analysis of population-based surveys from 138 low-income and middle-income countries found that 29% of children age 6 months to 5 years had vitamin A deficiency in 2013 [[23](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en23)]. Deficiency rates were highest in sub-Saharan Africa (48%) and South Asia (44%). In addition, approximately 10% to 20% of pregnant people in low-income countries have vitamin A deficiency [[24](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en24)].

The most common clinical sign of vitamin A deficiency is xerophthalmia, which develops after plasma retinol has been low and the eye’s vitamin A reserves have become depleted. The first sign is night blindness, or the inability to see in low light or darkness as a result of low rhodopsin levels in the retina [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1),[23](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en23),[24](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en24)]. Xerophthalmia also affects the cornea and can eventually lead to permanent blindness; vitamin A deficiency is one of the top causes of preventable blindness in children [[24](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en24)].

Chronic vitamin A deficiency has also been associated with abnormal lung development, respiratory diseases (such as pneumonia), and an increased risk of anemia and death [[22](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en22),[23](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en23),[25](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en25)].

Another effect of chronic vitamin A deficiency is increased severity and mortality risk of infections (particularly measles and infection-associated diarrhea) [[22](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en22)]. In 2013, 94,500 children in low-income and middle-income countries died of diarrhea and 11,200 died of measles as a result of vitamin A deficiency [[23](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en23)]. More than 95% of deaths attributable to vitamin A deficiency occurred in sub-Saharan Africa and Asia, where vitamin A deficiency was responsible for 2% of all deaths in children younger than 5 years [[23](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en23)].

## Groups at Risk of Vitamin A Inadequacy

The following groups are among those most likely to have inadequate intakes of vitamin A.

### Premature infants

Preterm infants have low liver stores of vitamin A at birth, and their plasma concentrations of retinol often remain low throughout the first year of life [[26](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en26),[27](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en27)]. Preterm infants with vitamin A deficiency have a higher risk of eye and chronic lung diseases [[28](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en28),[29](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en29)]. However, in high-income countries, clinical vitamin A deficiency is rare in infants and occurs only in those with malabsorption disorders [[30](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en30)].

### Infants, children, and pregnant and lactating persons in low-income and middle-income countries

Pregnant people need extra vitamin A for fetal growth and tissue maintenance and to support their own metabolism [[31-33](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en31)]. The breast milk of lactating people with adequate vitamin A intakes contains sufficient amounts of vitamin A to meet infants’ needs for the first 6 months of life [[34](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en34)]. However, in people with vitamin A deficiency, the vitamin A content of breast milk is not sufficient to maintain adequate vitamin A stores in infants who are exclusively breastfed [[34](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en34)].

About 190 million preschool-age children (one-third of all children in this age group), mostly in Africa and Southeast Asia, have vitamin A deficiency, according to the World Health Organization [[23](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en23),[35](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en35)]. They have a higher risk of visual impairment and of illness and death from childhood infections, such as measles and infections that cause diarrheal diseases [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1),[35](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en35)].

The World Health Organization estimates that 9.8 million pregnant people (15% of all pregnant people) around the world, mostly in low-income and middle-income countries, have xerophthalmia as a result of vitamin A deficiency [[36](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en36)].

### People with cystic fibrosis

Up to 90% of people with cystic fibrosis have pancreatic insufficiency, which increases their risk of vitamin A deficiency due to difficulty absorbing fat [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1),[37](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en37)]. Studies in Australia and the Netherlands indicate that 2% to 13% of children and adolescents with cystic fibrosis have vitamin A deficiency [[38](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en38),[39](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en39)]. As a result, standard care for cystic fibrosis includes lifelong treatment with vitamin A (daily amounts of 750 mcg RAE to 3,000 mcg RAE, depending on age, are recommended in the United States and Australia), other fat-soluble vitamins, and pancreatic enzymes [[37](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en37),[39](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en39)].

### Individuals with gastrointestinal disorders

Approximately one-quarter of children with Crohn’s disease and ulcerative colitis have vitamin A deficiency; adults with these disorders, especially those who have had the disorder for several years, also have a higher risk of vitamin A deficiency [[40](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en40),[41](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en41)]. Although some evidence supports the use of vitamin A supplements in people with these disorders [[42](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en42)], other research has found that supplementation offers no benefit [[43](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en43)]. Some children and adults with newly diagnosed celiac disease also have vitamin A deficiency; a gluten-free diet can, but does not always, eliminate this deficiency [[44-47](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en44)].

## Vitamin A and Health

This section focuses on three diseases and disorders in which vitamin A or carotenoids might play a role: cancer, age-related macular degeneration (AMD), and measles.

### Cancer

Because of its role in regulating cell growth and differentiation, several studies have examined the association between vitamin A and various types of cancer. However, the relationship between serum vitamin A levels or vitamin A supplementation and cancer risk or cancer-related death is unclear. This fact sheet does not include studies of all-trans retinoic acid, a vitamin A metabolite that is used as a drug in high doses to treat a form of leukemia [[48](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en48),[49](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en49)].

Several systematic reviews and meta-analyses of observational studies have shown that higher dietary intakes of retinol, carotenoids, fruits and vegetables, or a combination are associated with a lower risk of lung cancer [[50](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en50)], non-Hodgkin lymphoma [[51](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en51)], pancreatic cancer [[52](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en52)], oral cavity cancer [[53](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en53)], laryngeal cancer [[53](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en53)], esophageal cancer [[54](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en54)], ovarian cancer [[55](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en55),[56](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en56)], glioma [[57](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en57)], and bladder cancer [[58](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en58)]. However, other observational studies have found no association between intakes of different forms of vitamin A and risk of liver cancer [[59](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en59)], non-Hodgkin lymphoma [[60](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en60)], colorectal cancer [[61](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en61)], prostate cancer [[61](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en61)], or all cancers [[62](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en62)].

Some clinical trial evidence suggests that supplemental vitamin A might reduce the risk of certain cancers but increase the risk of other forms of cancer, cardiovascular disease morbidity and mortality, and all-cause mortality. Examples are provided below.

The Carotene and Retinol Efficacy Trial (CARET) included 18,314 male and female current and former smokers (with at least a 20 pack-year history [equivalent to smoking 1 pack per day for 20 years or 2 packs per day for 10 years, for example] of cigarette smoking) as well as some men occupationally exposed to asbestos (who also have a higher risk of lung cancer), all age 45–74 years. The study randomized participants to take supplements containing 30 mg beta-carotene plus 25,000 IU (7,500 mcg RAE) retinyl palmitate or a placebo daily for about 6 years to evaluate the potential effects on lung cancer risk [[63](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en63)]. The trial was ended prematurely after a mean of 4 years, partly because the supplements were unexpectedly found to have increased lung cancer risk by 28% and death from lung cancer by 46%; the supplements also increased the risk of all-cause mortality by 17%.

A subsequent study followed CARET participants for an additional 6 years after they stopped taking the study supplements [[64](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en64)]. During this time, the differences in lung cancer risk between the intervention and placebo groups were no longer statistically significant, with one exception: women in the intervention group had a 33% higher risk of lung cancer. In a separate analysis of CARET study data, men who took the two supplements had a 35% lower risk of nonaggressive prostate cancer during the 4-year active trial but not during the 6-year postintervention period. In contrast, men who took these two supplements in addition to another self-prescribed supplement (typically a multivitamin) had a 52% higher risk of aggressive prostate cancer during the active trial, but not during the postintervention period [[65](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en65)].

The Alpha-Tocopherol, Beta-Carotene (ATBC) Cancer Prevention Study also found that beta-carotene supplements increased the risk of lung cancer in smokers [[66](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en66)]. In this study, 29,133 male smokers age 50–69 years who smoked an average of 20.4 cigarettes a day for an average of 35.9 years took a supplement containing 50 mg/day alpha-tocopherol, 20 mg/day beta-carotene, both alpha-tocopherol and beta-carotene, or a placebo for 5–8 years. The beta-carotene supplements increased the risk of lung cancer by 18%, although they had little to no effect on the incidence of other cancers. The overall rate of death, primarily from lung cancer and ischemic heart disease, was 8% higher in participants who took beta-carotene. A subsequent study followed 25,563 of these participants for an additional 18 years [[67](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en67)]. During this period, participants were no longer taking the supplements, but most continued to smoke. Participants who had taken beta-carotene in the original trial did not have a higher risk of lung cancer, but they had a 20% higher risk of death due to prostate cancer.

The Age-Related Eye Disease Study 2 (AREDS2) was a 5-year randomized clinical trial with 4,203 participants age 50–85 years examining the effects on AMD of a dietary supplement containing several ingredients with or without beta-carotene (15 mg [7,500 mcg RAE]) [[68](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en68)]. No current smokers received the supplements containing beta-carotene. At the end of the trial, more lung cancers were discovered in the beta-carotene group than in the no beta-carotene group (23 vs. 11 cases), and 31 of the 34 affected were former smokers. In a follow-up analysis of 3,882 of the participants 5 years after the end of AREDS2 (during which they took the AREDS2 formulation containing lutein and zeaxanthin instead of beta-carotene), the increased lung cancer risk persisted, with an 82% higher risk among participants who took the supplement containing beta-carotene during the 5-year AREDS2 trial [[69](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en69)].

Three other clinical trials have found no relationship between taking vitamin A or beta-carotene supplements and lung cancer incidence or mortality [[70](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en70)]. One trial randomized 22,071 male physicians age 40–84 years to take 50 mg beta carotene on alternate days or a placebo for 12 years [[71](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en71)]. Eleven percent of the physicians were current smokers, and 38% were former smokers at the start of the study. The results showed no differences between the groups in number of cases of lung cancer or any malignant neoplasms or number of deaths from cancer. Another trial randomized 7,627 women (mean age 60.4 years) to take 50 mg beta-carotene on alternate days, 600 IU vitamin E on alternate days, 500 mg vitamin C daily, or a placebo for a mean of 9.4 years [[72](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en72)]. Fifteen percent of the women were current smokers, and 41% were former smokers at the start of the study. None of the supplements had any significant effect on total cancer incidence or cancer mortality, including from lung cancer. A third trial included 29,584 healthy men and women age 40–69 years who were living in Linxian, China, where micronutrient deficiencies are common [[73](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en73)]. The study randomized participants to take either a placebo or one of four vitamin and mineral combinations (including one providing retinol and zinc and another providing beta carotene, vitamin E, and selenium) for 5.25 years. The investigators followed participants for an additional 10 years after they stopped taking the supplements. The nutrient doses in the supplements were equivalent to or twice as high as U.S. recommended intakes, but the study report did not provide the exact doses. During both the intervention and follow-up periods, lung cancer death rates did not differ among the five groups, even when the investigators further analyzed the results for differences by age, sex, and smoking status.

The CARET and ATBC study results suggest that large supplemental doses of beta-carotene with or without retinyl palmitate have detrimental effects in current or former smokers and workers exposed to asbestos. However, the other studies described above that used similar vitamin A doses but had smaller proportions of current or former smokers do not raise this concern. Among nonsmokers, beta-carotene and vitamin A supplements do not appear to affect the risk of cancer.

### Age-related macular degeneration

AMD is the leading cause of significant vision loss in older people [[74](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en74)]. AMD’s etiology involves complex interactions among genetic susceptibility, environmental factors (including exposure to oxidative stress), and normal aging [[74](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en74)]. Because of the role of oxidative stress in AMD pathophysiology, supplements containing carotenoids with antioxidant functions, such as beta-carotene, lutein, and zeaxanthin, might be useful for preventing or treating this condition. Lutein and zeaxanthin (which are not precursors of vitamin A), in particular, accumulate in the retina, the tissue in the eye that is damaged by AMD.

The AREDS trial found that participants with a high risk of developing advanced AMD (i.e., those who had intermediate AMD or who had advanced AMD in one eye) had a 25% lower risk of developing advanced AMD after they took a daily supplement containing beta-carotene (15 mg [7,500 mcg RAE]), vitamin E (180 mg [400 IU] dl-alpha-tocopheryl acetate), vitamin C (500 mg), zinc (80 mg), and copper (2 mg) for 5 years than participants taking a placebo [[75](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en75)].

The follow-up AREDS2 study confirmed the value of this supplement in reducing the progression of AMD over a median follow-up period of 5 years [[68](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en68)]. However, this follow-up study showed that adding lutein (10 mg) and zeaxanthin (2 mg) or omega-3 fatty acids to the formulation produced no additional benefits. Importantly, the follow-up study also revealed that beta-carotene was not a required ingredient; the original AREDS formulation without beta-carotene provided the same protective effect against developing advanced AMD.

In a more detailed analysis, participants with the lowest dietary intakes of lutein and zeaxanthin had a 26% lower risk of advanced AMD when they took a supplement containing these two carotenoids than those who did not take a supplement with these carotenoids [[68](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en68)]. The risk of advanced AMD was also 18% lower in participants who took the modified AREDS supplement containing lutein and zeaxanthin but not beta-carotene than in participants who took the formulation with beta-carotene but not lutein or zeaxanthin.

A subsequent study monitored dietary intakes of several nutrients in 4,504 AREDS participants and 3,738 AREDS2 participants (mean age 71 years) for a median of 10.2 years [[76](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en76)]. Participants in the two highest quintiles of intakes for vitamin A, beta-carotene, or lutein and zeaxanthin had a lower risk of progression to late AMD. For example, the risk of late AMD was 18% lower among those in the fifth quintile for vitamin A intake and 20% lower among those in the fourth quintile than among those in the first quintile.

At the end of the 5-year AREDS2 trial, participants were all offered the final AREDS2 formulation that included lutein and zeaxanthin in place of beta-carotene. Researchers followed up with 3,882 of these participants for an additional 5 years [[69](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en69)]. After 10 years, participants who had taken the AREDS2 supplement with lutein and zeaxanthin had an additional 20% reduced risk of progression to late AMD compared with those who took the supplement containing beta-carotene. This finding confirmed the benefit of replacing beta-carotene with lutein and zeaxanthin.

Individuals who have or are developing AMD should talk to their health care provider about their vitamin A intakes and the supplement formulations used in the AREDS studies.

### Measles

In 2019, measles was responsible for more than 207,500 deaths around the world, mostly in young children in low-income countries [[77](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en77)]. A major risk factor for severe measles is vitamin A insufficiency. The World Health Organization recommends large oral doses of vitamin A for children living in areas with a high prevalence of vitamin A deficiency to prevent morbidity and mortality, including from measles [[35](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en35)]. Recommended doses are 30,000 mcg RAE (100,000 IU) of vitamin A once for infants age 6–11 months and 60,000 mcg RAE (200,000 IU) every 4–6 months for age 1–5 years.

In 2013, 11,200 deaths from measles were associated with vitamin A deficiency, and more than 95% of these deaths occurred in sub-Saharan Africa and south Asia. In a pooled analysis of randomized controlled trials (RCTs) within this study, vitamin A supplementation was associated with a 26% lower risk of dying from measles. However, a Cochrane Review that included six RCTs of vitamin A supplementation (15,000 mcg RAE [50,000 IU] to 60,000 mcg RAE [200,000 IU], depending on age) found that the supplementation did not affect risk of death due to measles, although it did help prevent new cases of measles [[78](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en78)]. These RCTs assessed the value of supplementation to prevent morbidity and mortality due to measles in a total of 19,566 children age 6 months to 5 years.

## Health Risks from Excessive Vitamin A

Because vitamin A is fat soluble, the body stores excess amounts, primarily in the liver, and these levels can accumulate.

Acute vitamin A toxicity, also referred to as hypervitaminosis A, occurs within days to weeks after someone ingests one or a few very high doses (typically more than 100 times the RDA) [[79](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en79)]. Resulting signs and symptoms typically include severe headache, blurred vision, nausea, dizziness, aching muscles, and coordination problems. In severe cases, cerebral spinal fluid pressure can increase, leading to drowsiness and, eventually, coma and even death [[79](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en79)].

Chronic hypervitaminosis A (regular consumption of high doses) can cause dry skin, painful muscles and joints, fatigue, depression, and abnormal liver test results [[79](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en79)].

Total intakes of preformed vitamin A that exceed the UL as well as some retinoid medications used as topical therapies (such as isotretinoin, used to treat severe acne, and etretinate, a treatment for severe psoriasis) can cause congenital birth defects [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1)]. These birth defects can include malformations of the eye, skull, lungs, and heart [[10](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en10)]. Experts advise people who are or might be pregnant and those who are lactating not to take high doses (more than 3,000 mcg RAE [10,000 IU] daily) of vitamin A supplements [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1)].

Unlike preformed vitamin A, beta-carotene is not known to be teratogenic or lead to reproductive toxicity [[1](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en1)]. The most common effect of long-term, excess beta-carotene is carotenodermia, a harmless condition in which the skin becomes yellow-orange [[3](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en3)]. This condition can be reversed by discontinuing beta-carotene ingestion. However, the ATBC trial found that supplementation with a large amount of beta-carotene (20 mg/day), with or without 50 mg/day vitamin E, for 5–8 years increased the risk of lung cancer and mortality (mainly from lung cancer and ischemic heart disease) in male smokers [[66](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en66)]. The CARET trial also showed that supplementation with a large amount of beta-carotene (30 mg/day) plus 7,500 mcg RAE (25,000 IU)/day retinyl palmitate for 4–8 years in current and former smokers as well as some men occupationally exposed to asbestos increased the risk of lung cancer and death from lung cancer [[63](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en63)].

The FNB has not established ULs for beta-carotene and other provitamin A carotenoids [[3](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en3)]. However, the FNB advises against the use of beta-carotene supplements for the general population, except as a provitamin A source to prevent vitamin A deficiency.

### Tolerable upper intake levels for preformed vitamin A

The FNB has established ULs for preformed vitamin A that apply to both food and supplement intakes [[5](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en5)]. The FNB based these ULs on the amounts associated with an increased risk of liver abnormalities in men and women, teratogenic effects, and several toxic effects in infants and children.

| **Table 3: Tolerable Upper Intake Levels (ULs) for Preformed Vitamin A [**[**5**](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en5)**]\*** | | | | |
| --- | --- | --- | --- | --- |
| **Age** | **Male** | **Female** | **Pregnancy** | **Lactation** |
| Birth to 12 months | 600 mcg | 600 mcg |  |  |
| 1–3 years | 600 mcg | 600 mcg |  |  |
| 4–8 years | 900 mcg | 900 mcg |  |  |
| 9–13 years | 1,700 mcg | 1,700 mcg |  |  |
| 14–18 years | 2,800 mcg | 2,800 mcg | 2,800 mcg | 2,800 mcg |
| 19+ years | 3,000 mcg | 3,000 mcg | 3,000 mcg | 3,000 mcg |

\*These ULs apply only to products from animal sources and supplements whose vitamin A comes entirely from retinol or its ester forms, such as retinyl palmitate. However, many dietary supplements (such as multivitamins) do not provide all of their vitamin A in retinol or its ester forms. For example, the vitamin A in some supplements consists partly or entirely of beta-carotene. In such cases, the percentage of retinol or retinyl ester in the supplement should be used to determine whether an individual’s vitamin A intake exceeds the UL. For example, a supplement whose label indicates that the product contains 3,000 mcg RAE vitamin A and that 60% of this vitamin A comes from beta-carotene (and therefore 40% comes from retinol or retinyl ester) provides 1,200 mcg RAE of preformed vitamin A. That amount is above the UL for children from birth to 8 years but below the UL for older children and adults.

## Interactions with Medications

Vitamin A has the potential to interact with certain medications. In addition, several types of medications might adversely affect vitamin A levels. A few examples are provided below. Individuals taking these and other medications on a regular basis should discuss their vitamin A status with their health care providers.

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Orlistat (Alli, Xenical), a weight-loss treatment, can decrease the absorption of vitamin A, other fat-soluble vitamins, and beta-carotene, resulting in low plasma levels in some patients [[80](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en80),[81](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en81)]. The manufacturers of Alli and Xenical recommend that patients on orlistat take a multivitamin supplement containing vitamin A and beta-carotene as well as other fat-soluble vitamins [[82](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en82),[83](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en83)].

### Retinoids

Several synthetic retinoids derived from vitamin A are used orally as prescription medicines. Examples include the psoriasis treatment acitretin (Soriatane) and bexarotene (Targretin), used to treat the skin effects of T-cell lymphoma. Retinoids can increase the risk of hypervitaminosis A when taken in combination with vitamin A supplements [[81](https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/#en81)].

## Vitamin A and Healthful Diets

The federal government’s 2020–2025 Dietary Guidelines for Americans notes that “Because foods provide an array of nutrients and other components that have benefits for health, nutritional needs should be met primarily through foods. … In some cases, fortified foods and dietary supplements are useful when it is not possible otherwise to meet needs for one or more nutrients (e.g., during specific life stages such as pregnancy).”

For more information about building a healthy dietary pattern, refer to the [Dietary Guidelines for Americans](https://www.dietaryguidelines.gov/)[external link disclaimer](https://ods.od.nih.gov/About/exit_disclaimer.aspx) and the USDA’s [MyPlate](https://www.myplate.gov/)[external link disclaimer](https://ods.od.nih.gov/About/exit_disclaimer.aspx).

The Dietary Guidelines for Americans describes a healthy eating pattern as one that

* Includes a variety of vegetables, fruits, whole grains, fat-free or low-fat milk and milk products, and oils.
  + Many fruits, vegetables, and dairy products are good sources of vitamin A. Some ready-to-eat breakfast cereals are fortified with vitamin A.
* Includes a variety of protein foods, including seafood, lean meats and poultry, eggs, legumes (beans and peas), nuts, seeds, and soy products.
  + Beef liver contains high amounts of vitamin A. Other sources of the nutrient include eggs and some fish.
* Limits foods and beverages higher in added sugars, saturated fat, and sodium.
* Limits alcoholic beverages.
* Stays within your daily calorie needs.

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## Disclaimer

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# Biotin

## Introduction

Biotin, a B vitamin, is an essential nutrient that is naturally present in some foods and available as a dietary supplement. This water-soluble vitamin is a cofactor for five carboxylases (propionyl-CoA carboxylase, pyruvate carboxylase, methylcrotonyl-CoA carboxylase [MCC], acetyl-CoA carboxylase 1, and acetyl-CoA carboxylase 2) that catalyze critical steps in the metabolism of fatty acids, glucose, and amino acids [[1-5](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en1)]. Biotin also plays key roles in histone modifications, gene regulation (by modifying the activity of transcription factors), and cell signaling [[3](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en3)].

Most biotin in foods is bound to protein, although some dietary biotin is in the free form [[1](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en1),[3](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en3),[4](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en4),[6](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en6)]. Gastrointestinal proteases and peptidases break down the protein-bound forms of ingested biotin into biocytin and biotin-oligopeptides, which undergo further processing by biotinidase, an enzyme, in the intestinal lumen to release free biotin [[6](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en6)]. The free biotin is then absorbed in the small intestine, and most biotin is stored in the liver [[1](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en1),[3](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en3),[6](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en6)].

A limited number of reliable indicators of biotin status is available [[7](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en7)]. In healthy adults, the concentration of biotin is 133–329 pmol/L in serum and 18–127 nmol/24 hours in urine [[2](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en2)]. Abnormally low urinary excretion of biotin is an indicator of biotin deficiency, as is abnormally high excretion of 3-hydroxyisovaleric acid (higher than 3.3 mmol/mol creatinine) or 3-hydroxyisovalerylcarnitine (higher than 0.06 mmol/mol creatinine) resulting from reduced activity of MCC [[2](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en2),[7](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en7),[8](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en8)]. The most reliable individual markers of biotin status, including deficiency and sufficiency, are biotinylated MCC and propionyl-CoA carboxylase in white blood cells [[7](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en7)]. Oral administration of large doses of biotin increases serum concentrations of biotin and its metabolites [[1](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en1),[9](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en9)]. However, serum concentrations of biotin and its catabolites are not good indicators of marginal biotin deficiency because they do not decrease sufficiently in people with marginal biotin deficiency for these changes to be detectable with existing tests [[3](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en3),[10](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en10)].

## Recommended Intakes

Intake recommendations for biotin and other nutrients are provided in the Dietary Reference Intakes (DRIs) developed by the Food and Nutrition Board (FNB) at the National Academies of Sciences, Engineering, and Medicine [[1](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en1)]. DRI is the general term for a set of reference values used for planning and assessing nutrient intakes of healthy people. These values, which vary by age and sex, include the following:

* Recommended Dietary Allowance (RDA): Average daily level of intake sufficient to meet the nutrient requirements of nearly all (97%–98%) healthy individuals; often used to plan nutritionally adequate diets for individuals
* Adequate Intake (AI): Intake at this level is assumed to ensure nutritional adequacy; established when evidence is insufficient to develop an RDA
* Estimated Average Requirement (EAR): Average daily level of intake estimated to meet the requirements of 50% of healthy individuals; usually used to assess the nutrient intakes of groups of people and to plan nutritionally adequate diets for them; can also be used to assess the nutrient intakes of individuals
* Tolerable Upper Intake Level (UL): Maximum daily intake unlikely to cause adverse health effects

The FNB found the available data to be insufficient to derive an EAR and RDA for biotin. For this reason, the FNB established only AIs for biotin. The FNB based its determination of AIs for all populations on the amount of biotin in human milk consumed by infants and then used body weight to extrapolate AIs for other groups [[11](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en11)]. Table 1 lists the current AIs for biotin [[1](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en1)].

| **Table 1: Adequate Intakes (AIs) for Biotin [**[**1**](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en1)**]** | | | | |
| --- | --- | --- | --- | --- |
| **Age** | **Male** | **Female** | **Pregnancy** | **Lactation** |
| Birth to 6 months | 5 mcg | 5 mcg |  |  |
| 7–12 months | 6 mcg | 6 mcg |  |  |
| 1–3 years | 8 mcg | 8 mcg |  |  |
| 4–8 years | 12 mcg | 12 mcg |  |  |
| 9–13 years | 20 mcg | 20 mcg |  |  |
| 14–18 years | 25 mcg | 25 mcg | 30 mcg | 35 mcg |
| 19+ years | 30 mcg | 30 mcg | 30 mcg | 35 mcg |

## Sources of Biotin

### Food

Many foods contain some biotin. Foods that contain the most biotin include organ meats, eggs, fish, meat, seeds, nuts, and certain vegetables (such as sweet potatoes) [[2](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en2),[12](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en12)]. The biotin content of food can vary; for example, plant variety and season can affect the biotin content of cereal grains, and certain processing techniques (e.g., canning) can reduce the biotin content of foods [[12](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en12)].

Dietary avidin, a glycoprotein in raw egg whites, binds tightly to dietary biotin and prevents biotin’s absorption in the gastrointestinal tract [[13](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en13),[14](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en14)]. Cooking denatures avidin, making it unable to interfere with biotin absorption [[13](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en13)].

Several food sources of biotin are listed in Table 2.

| **Table 2: Biotin Content of Selected Foods [**[**5**](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en5)**]** | | |
| --- | --- | --- |
| **Food** | **Micrograms (mcg) per serving** | **Percent DV\*** |
| Beef liver, cooked, 3 ounces | 30.8 | 103 |
| Egg, whole, cooked | 10.0 | 33 |
| Salmon, pink, canned in water, 3 ounces | 5.0 | 17 |
| Pork chop, cooked, 3 ounces | 3.8 | 13 |
| Hamburger patty, cooked, 3 ounces | 3.8 | 13 |
| Sunflower seeds, roasted, ¼ cup | 2.6 | 9 |
| Sweet potato, cooked, ½ cup | 2.4 | 8 |
| Almonds, roasted, ¼ cup | 1.5 | 5 |
| Tuna, canned in water, 3 ounces | 0.6 | 2 |
| Spinach, boiled, ½ cup | 0.5 | 2 |
| Broccoli, fresh, ½ cup | 0.4 | 1 |
| Cheddar cheese, mild, 1 ounce | 0.4 | 1 |
| Milk, 2%, 1 cup | 0.3 | 1 |
| Plain yogurt, 1 cup | 0.2 | 1 |
| Oatmeal, 1 cup | 0.2 | 1 |
| Banana, ½ cup | 0.2 | 1 |
| Whole wheat bread, 1 slice | 0.0 | 0 |
| Apple, ½ cup | 0.0 | 0 |

\*DV = Daily Value. The U.S. Food and Drug Administration (FDA) developed DVs to help consumers compare the nutrient contents of foods and dietary supplements within the context of a total diet. The DV for biotin is 30 mcg for adults and children age 4 years and older [[15](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en15)]. FDA does not require food labels to list biotin content unless biotin has been added to the food. Foods providing 20% or more of the DV are considered to be high sources of a nutrient, but foods providing lower percentages of the DV also contribute to a healthful diet.

The U.S. Department of Agriculture’s (USDA’s) [FoodData Central](https://fdc.nal.usda.gov/)[external link disclaimer](https://ods.od.nih.gov/About/exit_disclaimer.aspx) does not list the biotin content of foods or provide lists of foods containing biotin.

### Dietary supplements

Biotin is available in dietary supplements containing biotin only, in supplements containing combinations of B-complex vitamins, and in some multivitamin/mineral products [[16](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en16)]. The absorption rate of oral, free biotin is 100%, even when people consume pharmacologic doses of up to 20 mg/day biotin [[17](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en17)].

## Biotin Intakes and Status

Although there are no nationally representative estimates of biotin intakes in the United States, the average biotin intake from foods in other western populations is about 35–70 mcg/day, indicating that most people in these countries consume adequate amounts of biotin [[2](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en2),[3](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en3)].

## Biotin Deficiency

Biotin deficiency is rare [[12](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en12),[18](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en18)], and severe biotin deficiency in healthy individuals eating a normal mixed diet has never been reported [[13](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en13)].

The signs and symptoms of biotin deficiency typically appear gradually and can include thinning hair with progression to loss of all hair on the body; scaly, red rash around body openings (eyes, nose, mouth, and perineum); conjunctivitis; ketolactic acidosis (which occurs when lactate production exceeds lactate clearance) and aciduria (abnormal amounts of acid in urine); seizures; skin infection; brittle nails; neurological findings (e.g., depression, lethargy, hallucinations, and paresthesias of the extremities) in adults; and hypotonia, lethargy, and developmental delay in infants [[2](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en2),[3](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en3),[13](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en13)]. The rash and unusual distribution of facial fat in people with biotin deficiency is known as biotin deficiency facies [[1](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en1),[13](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en13)].

## Groups at Risk of Biotin Inadequacy

The following groups are among those most likely to have inadequate biotin status.

### Individuals with biotinidase deficiency

Biotinidase deficiency is a rare autosomal recessive disorder that prevents the body from releasing free biotin, leading to biotin deficiency despite normal intake. Without treatment, biotinidase deficiency produces neurological and cutaneous symptoms, and profound biotinidase deficiency can lead to coma or death [[19](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en19),[20](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en20)]. Because treatment with oral biotin starting at birth (or before symptoms develop) and continuing for the rest of the person’s life can prevent these symptoms, all newborns in the United States and many other countries are screened for this disorder [[19](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en19),[20](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en20)].

### Individuals with chronic alcohol exposure

Chronic exposure to alcohol inhibits the absorption of biotin [[21](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en21)]. Plasma biotin concentrations are low in 15% of people with chronic alcoholism [[12](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en12)].

### Pregnant and breastfeeding women

At least a third of pregnant women develop marginal biotin deficiency in spite of normal biotin intakes; plasma and breastmilk concentrations of biotin decrease in lactating women, even when their dietary biotin intakes exceed the AI [[2](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en2),[18](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en18),[22](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en22)]. Additional research is needed to understand the clinical significance of these findings.

## Biotin and Health

### Hair, nail, and skin health

Signs of biotin deficiency include skin rashes, hair loss, and brittle nails [[10](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en10),[13](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en13)]. Therefore, biotin supplements are often promoted for hair, skin, and nail health [[16](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en16),[23](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en23),[24](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en24)]. However, these claims are supported, at best, by only a few case reports and small studies.

The evidence on biotin supplementation to treat brittle nails includes three small studies that did not include a placebo group, and these reports do not indicate the baseline biotin status of study participants. One of these studies assessed the effects of 2.5 mg/day biotin for 6–15 months in 22 women with brittle, splitting, or soft nails and 10 healthy volunteers [[25](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en25)]. In the eight patients with brittle nails whose nail samples were obtained immediately before and after biotin supplementation, nail thickness increased by 25%. In the 14 patients with brittle nails whose nail specimens were obtained 2–4 months after starting treatment and 1–4 months after ending treatment, nail thickness increased by 7%, a difference that was not statistically significant. In the second study, 2.5 mg biotin daily for an average of 5.5 months in 45 patients with thin and brittle fingernails resulted in firmer and harder fingernails in 41 of the patients (91%) [[26](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en26)]. Finally, the third, retrospective study in 35 patients with brittle nails found that 2.5 mg/day biotin for 6–15 months resulted in clinical improvement in 22 of the 35 patients (63%) [[27](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en27)].

Only case reports are available to support claims that biotin supplements can promote hair health, and these reports were only in children [[28](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en28),[29](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en29)]. These studies found that 3–5 mg/day biotin in children with uncombable hair syndrome (a rare disorder of the hair shaft) significantly improved hair health after 3–4 months. The evidence supporting the use of biotin supplements to support skin health is equally limited to a small number of case reports, all in infants, showing that 100 mcg to 10 mg/day resulted in dramatic improvements in rash or dermatitis as well as alopecia [[30](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en30),[31](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en31)].

Future studies are needed to determine whether biotin supplements might improve hair, nail, and skin health, especially among healthy individuals.

## Health Risks from Excessive Biotin

The FNB was unable to establish ULs for biotin because there is no evidence in humans that biotin is toxic at high intakes [[1](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en1)]. Several studies have found no adverse effects of 10–50 mg/day biotin, and up to 200 mg/day oral biotin or 20 mg/day intravenously in patients with biotinidase deficiency do not produce symptoms of toxicity [[1](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en1),[10](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en10)].

High biotin intakes, and potentially even intakes greater than the AI, may pose another type of health risk [[32](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en32)]. Supplementing with biotin beyond recommended intakes can cause clinically significant falsely high or falsely low laboratory test results, depending on the test. These incorrect results may lead to inappropriate patient management or misdiagnosis of a medical condition. The following section has more details on these interactions.

## Interactions with Laboratory Tests

Very high intakes of biotin may interfere with diagnostic assays that use biotin-streptavidin technology and are commonly used to measure levels of hormones (such as thyroid hormone) and other analytes such as 25-hydroxyvitamin D, producing falsely normal or abnormal results [[9](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en9),[32](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en32)]. As a result, a few recent case reports have described findings falsely indicating Graves’ disease and severe hyperthyroidism in patients taking 10–300 mg biotin per day, including six children receiving high doses of biotin (2–15 mg/kg body weight per day) to treat inherited metabolic diseases [[33-37](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en33)].

Even a single 10 mg dose of biotin has interfered with thyroid function tests administered within 24 hours of taking the supplement [[38](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en38)]. A small study in six healthy adults who took 10 mg/day of supplemental biotin for 1 week found interference in several biotinylated assays, including falsely decreased levels of thyroid stimulating hormone (which could lead to a misdiagnosis of thyrotoxicosis) and N-terminal pro-brain natriuretic peptide (which could result in a failure to identify congestive heart failure) [[9](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en9)]. According to FDA, a patient with a high intake of supplemental biotin died following a troponin test (to help diagnose a heart attack) that gave a falsely low result because the test was subject to biotin interference [[32](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en32)].

FDA advises health care providers to ask their patients about any supplements they may be taking that contain biotin and to consider biotin interference as a possible source of error if laboratory test results do not match the clinical presentation of the patient [[32](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en32)].

## Interactions with Medications

Biotin can interact with certain medications, and some medications can have an adverse effect on biotin levels. One example is provided below. Individuals taking this and other medications on a regular basis should discuss their biotin status with their health care providers.

### Anticonvulsants

In a study in 264 people with epilepsy, anticonvulsant treatment for at least 1 year was associated with significantly lower serum biotin levels than in control group patients [[39](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en39)]. The anticonvulsants used included carbamazepine (Tegretol, Carbatrol, Epitol, Equetro), primidone (Mysoline), phenytoin (Dilantin, Phenytek), and phenobarbital (Luminal, Solfoton) as well as combinations of these medications. A few other, smaller studies have found similar results [[40](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en40),[41](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en41)]. The reason could be that anticonvulsant treatment increases biotin catabolism, which leads to reduced biotin status and inhibition of intestinal biotin absorption [[40](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en40),[42](https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/#en42)].

## Biotin and Healthful Diets

The federal government’s 2020–2025 Dietary Guidelines for Americans notes that “Because foods provide an array of nutrients and other components that have benefits for health, nutritional needs should be met primarily through foods. … In some cases, fortified foods and dietary supplements are useful when it is not possible otherwise to meet needs for one or more nutrients (e.g., during specific life stages such as pregnancy).”

For more information about building a healthy dietary pattern, refer to the [Dietary Guidelines for Americans](https://www.dietaryguidelines.gov/)[external link disclaimer](https://ods.od.nih.gov/About/exit_disclaimer.aspx) and the USDA’s [MyPlate.](https://www.myplate.gov/)[external link disclaimer](https://ods.od.nih.gov/About/exit_disclaimer.aspx)

The Dietary Guidelines for Americans describes a healthy dietary pattern as one that

* Includes a variety of vegetables; fruits; grains (at least half whole grains); fat-free and low-fat milk, yogurt, and cheese; and oils.
  + Some fruits, vegetables, dairy products, and whole grains contain biotin.
* Includes a variety of protein foods such as lean meats; poultry; eggs; seafood; beans, peas, and lentils; nuts and seeds; and soy products.
  + ​​​​​​​Eggs and some organ meats are good sources of biotin; many nuts, seeds, seafood, and lean meats contain biotin.
* Limits foods and beverages higher in added sugars, saturated fat, and sodium.
* Limits alcoholic beverages.
* Stays within your daily calorie needs.

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# Calcium

## Introduction

Calcium, the most abundant mineral in the body, is found in some foods, added to others, present in some medicines (such as antacids), and available as a dietary supplement.

Calcium makes up much of the structure of bones and teeth and allows normal bodily movement by keeping tissue rigid, strong, and flexible [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. The small ionized pool of calcium in the circulatory system, extracellular fluid, and various tissues mediates blood vessel contraction and dilation, muscle function, blood clotting, nerve transmission, and hormonal secretion [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1),[2](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en2)].

Calcium from foods and dietary supplements is absorbed by both active transport and by passive diffusion across the intestinal mucosa [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1),[3](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en3)]. Active transport is responsible for most absorption when calcium intakes are lower, and passive diffusion accounts for an increasing proportion of calcium absorption as intakes rise. Vitamin D is required for calcium to be absorbed in the gut by active transport and to maintain adequate calcium levels in blood [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)].

Almost all (98%) calcium in the body is stored in the bones, and the body uses the bones as a reservoir for, and source of, calcium to maintain calcium homeostasis [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. More than 99% of calcium in the body is in the form of calcium hydroxyapatite, an inorganic matrix of calcium and phosphate that is stored in the bones and teeth [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1),[4](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en4),[5](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en5)]. Unlike teeth, bone undergoes continuous remodeling, with constant resorption and deposition of calcium into new bone [[4](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en4)]. Bone remodeling is required to change bone size during growth, repair damage, maintain serum calcium levels, and provide a source of other minerals [[4](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en4)].

At birth, the body contains about 26 to 30 g calcium. This amount rises quickly after birth, reaching about 1,200 g in women and 1,400 g in men by adulthood [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. These levels remain constant in men, but they start to drop in women as a result of increases in bone remodeling due to decreased estrogen production at the start of menopause [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)].

An inverse relationship exists between calcium intake and absorption. Absorption of calcium from food is about 45% at intakes of 200 mg/day but only 15% when intakes are higher than 2,000 mg/day [[6](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en6)]. Age can also affect absorption of dietary calcium [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1),[4](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en4)]. Net absorption of dietary calcium is as high as 60% in infants and young children, who need substantial amounts to build bone, but it decreases to about 25% in adulthood and continues to decline with age [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)].

Total calcium levels can be measured in serum or plasma; serum levels are typically 8.8 to 10.4 mg/dL (2.2 to 2.6 mmol/L) in healthy people [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1),[7](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en7)]. However, serum levels do not reflect nutritional status because of their tight homeostatic control [[4](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en4)]. Levels of ionized (or free) calcium, the biologically active form, in serum are also used to measure calcium status. The normal range of ionized calcium in healthy people is 4.6 to 5.3 mg/dL (1.15 to 1.33 mmol/L) [[7](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en7)]. Dual x-ray absorptiometry testing of bone mineral density can be used to assess cumulative calcium status over the lifetime because the skeleton stores almost all calcium in the body [[3](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en3)].

## Recommended Intakes

Intake recommendations for calcium and other nutrients are provided in the Dietary Reference Intakes (DRIs) developed by the Food and Nutrition Board (FNB) at the National Academies of Sciences, Engineering, and Medicine [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. DRI is the general term for a set of reference values used for planning and assessing nutrient intakes of healthy people. These values, which vary by age and sex, include the following:

* Recommended Dietary Allowance (RDA): Average daily level of intake sufficient to meet the nutrient requirements of nearly all (97%–98%) healthy individuals; often used to plan nutritionally adequate diets for individuals
* Adequate Intake (AI): Intake at this level is assumed to ensure nutritional adequacy; established when evidence is insufficient to develop an RDA
* Estimated Average Requirement (EAR): Average daily level of intake estimated to meet the requirements of 50% of healthy individuals; usually used to assess the nutrient intakes of groups of people and to plan nutritionally adequate diets for them; can also be used to assess the nutrient intakes of individuals
* Tolerable Upper Intake Level (UL): Maximum daily intake unlikely to cause adverse health effects

Table 1 lists the current RDAs for calcium [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. For adults, the main criterion that the FNB used to establish the RDAs was the amount needed to promote bone maintenance and neutral calcium balance. For infants age 0 to 12 months, the FNB established an AI that is equivalent to the mean intake of calcium in healthy, breastfed infants. For children and adolescents, the RDAs are based on intakes associated with bone accumulation and positive calcium balance.

| **Table 1: Recommended Dietary Allowances (RDAs) for Calcium [**[**1**](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)**]** | | | | |
| --- | --- | --- | --- | --- |
| **Age** | **Male** | **Female** | **Pregnant** | **Lactating** |
| 0–6 months\* | 200 mg | 200 mg |  |  |
| 7–12 months\* | 260 mg | 260 mg |  |  |
| 1–3 years | 700 mg | 700 mg |  |  |
| 4–8 years | 1,000 mg | 1,000 mg |  |  |
| 9–13 years | 1,300 mg | 1,300 mg |  |  |
| 14–18 years | 1,300 mg | 1,300 mg | 1,300 mg | 1,300 mg |
|  |  |  |  |  |
| 19–50 years | 1,000 mg | 1,000 mg | 1,000 mg | 1,000 mg |
|  |  |  |  |  |
| 51–70 years | 1,000 mg | 1,200 mg |  |  |
| >70+ years | 1,200 mg | 1,200 mg |  |  |

\*Adequate Intake (AI)

## Sources of Calcium

### Food

Milk, yogurt, and cheese are rich natural sources of calcium [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. In the United States, approximately 72% of calcium intakes come from dairy products and foods with added dairy ingredients [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. Nondairy sources include canned sardines and salmon with bones as well as certain vegetables, such as kale, broccoli, and Chinese cabbage (bok choi). Most grains do not have high amounts of calcium unless they are fortified. However, they contribute to calcium intakes, even though they contain small amounts of calcium, because people consume them frequently [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. Foods fortified with calcium in the United States include many fruit juices and drinks, tofu, and ready-to-eat cereals [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1),[8](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en8)]. Calcium citrate malate is a well-absorbed form of calcium used in some fortified juices [[3](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en3)].

Calcium absorption varies by type of food. The absorption of calcium from dairy products and fortified foods is about 30% [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. Certain compounds in plants (e.g., oxalic acid, phytic acid) can decrease calcium absorption by forming indigestible salts with calcium, decreasing its absorption [[3](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en3)]. As a result, absorption of calcium is only 5% for spinach, whereas it is much higher, at 27%, for milk [[3](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en3)]. In addition to spinach, foods with high levels of oxalic acid include collard greens, sweet potatoes, rhubarb, and beans [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. The bioavailability of calcium from other plants that do not contain these compounds—including broccoli, kale, and cabbage—is similar to that of milk, although the amount of calcium per serving is much lower [[3](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en3)]. When people eat many different types of foods, these interactions with oxalic or phytic acid probably have little or no nutritional consequences. Net absorption of dietary calcium is also reduced to a small extent by intakes of caffeine and phosphorus and to a greater extent by low status of vitamin D [[9-11](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en9)].

A variety of foods and their calcium content are listed in Table 2.

| **Table 2: Calcium Content of Selected Foods [**[**12**](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en12)**]** | | |
| --- | --- | --- |
| **Food** | **Milligrams (mg) per serving** | **Percent DV\*** |
| Yogurt, plain, low fat, 8 ounces | 415 | 32 |
| Orange juice, calcium fortified, 1 cup | 349 | 27 |
| Yogurt, fruit, low fat, 8 ounces | 344 | 27 |
| Mozzarella, part skim, 1.5 ounces | 333 | 26 |
| Sardines, canned in oil, with bones, 3 ounces | 325 | 25 |
| Milk, nonfat, 1 cup\*\* | 299 | 23 |
| Soymilk, calcium fortified, 1 cup | 299 | 23 |
| Milk, whole (3.25% milk fat), 1 cup\*\* | 276 | 21 |
| Tofu, firm, made with calcium sulfate, ½ cup\*\*\* | 253 | 19 |
| Salmon, pink, canned, solids with bones, 3 ounces | 181 | 14 |
| Cottage cheese, 1% milk fat, 1 cup | 138 | 11 |
| Tofu, soft, made with calcium sulfate, ½ cup\*\*\* | 138 | 11 |
| Soybeans, cooked, ½ cup | 131 | 10 |
| Breakfast cereals, fortified with 10% of the DV for calcium, 1 serving | 130 | 10 |
| Spinach, boiled, drained, ½ cup | 123 | 9 |
| Frozen yogurt, vanilla, soft serve, ½ cup | 103 | 8 |
| Turnip greens, fresh, boiled, ½ cup | 99 | 8 |
| Kale, fresh, cooked, 1 cup | 94 | 7 |
| Chia seeds, 1 tablespoon | 76 | 6 |
| Chinese cabbage (bok choi), raw, shredded, 1 cup | 74 | 6 |
| Beans, pinto, canned, drained, ½ cup | 54 | 4 |
| Tortilla, corn, one, 6” diameter | 46 | 4 |
| Sour cream, reduced fat, 2 tablespoons | 31 | 2 |
| Bread, whole wheat, 1 slice | 30 | 2 |
| Kale, raw, chopped, 1 cup | 24 | 2 |
| Broccoli, raw, ½ cup | 21 | 2 |
| Apple, golden delicious, with skin, 1 medium | 10 | 0 |

\* DV = Daily Value. The U.S. Food and Drug Administration (FDA) developed DVs to help consumers compare the nutrient contents of foods and dietary supplements within the context of a total diet. The DV for calcium is 1,300 mg for adults and children age 4 years and older [[13](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en13)]. FDA requires food labels to list calcium content. Foods providing 20% or more of the DV are considered to be high sources of a nutrient, but foods providing lower percentages of the DV also contribute to a healthful diet.  
\*\* Calcium content varies slightly by fat content; the more fat in the food, the less calcium it contains.  
\*\*\* Calcium content is for tofu processed with a calcium salt. Tofu processed with other salts does not provide significant amounts of calcium.

The U.S. Department of Agriculture’s (USDA’s) [FoodData Central](https://fdc.nal.usda.gov/)[external link disclaimer](https://ods.od.nih.gov/About/exit_disclaimer.aspx) lists the nutrient content of many foods and provides a comprehensive list of foods containing calcium arranged by [nutrient content](https://ods.od.nih.gov/pubs/usdandb/Calcium-Content.pdf) and by [food name](https://ods.od.nih.gov/pubs/usdandb/Calcium-Food.pdf).

### Dietary supplements

Calcium is available in many dietary supplements, including multivitamin/mineral products and supplements containing calcium only or calcium plus vitamin D [[14](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en14)]. Amounts of calcium in supplements vary widely; multivitamin/mineral supplements commonly contain about 200 to 300 mg, and common amounts in calcium or calcium plus vitamin D supplements are 500 or 600 mg [[14](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en14)].

The two most common forms of calcium in supplements are calcium carbonate and calcium citrate [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. In people with low levels of stomach acid, the solubility rate of calcium carbonate is lower, which could reduce the absorption of calcium from calcium carbonate supplements unless they are taken with a meal [[3](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en3)]. Calcium citrate is less dependent on stomach acid for absorption than calcium carbonate, so it can be taken without food [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. In general, however, absorption of calcium supplements is greater when they are taken with food, regardless of whether the user’s gastric acid is low [[3](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en3)]. Other calcium forms in supplements include calcium sulfate, ascorbate, microcrystalline hydroxyapatite, gluconate, lactate, and phosphate [[14](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en14)].

The forms of calcium in supplements contain varying amounts of elemental calcium. For example, calcium carbonate is 40% calcium by weight, whereas calcium citrate is 21% calcium [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. Elemental calcium is listed in the Supplement Facts panel, so consumers do not need to calculate the amount of calcium supplied by various forms of calcium in supplements.

The percentage of calcium absorbed from supplements, as with that from foods, depends not only on the source of calcium but also on the total amount of elemental calcium consumed at one time; as the amount increases, the percentage absorbed decreases. Absorption from supplements is highest with doses of 500 mg or less [[15](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en15)]. For example, the body absorbs about 36% of a 300 mg calcium dose and 28% of a 1,000 mg dose [[16](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en16)].

Some individuals who take calcium supplements might experience gastrointestinal side effects, including gas, bloating, constipation, or a combination of these symptoms. Calcium carbonate appears to cause more of these side effects than calcium citrate, especially in older adults who have lower levels of stomach acid [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. Symptoms can be alleviated by switching to a supplement containing a different form of calcium, taking smaller calcium doses more often during the day, or taking the supplement with meals.

### Medicines

Because of its ability to neutralize stomach acid, calcium carbonate is contained in some over-the-counter antacid products, such as Tums and Rolaids. Depending on its strength, each chewable pill or soft chew provides about 270 to 400 mg of calcium [[14](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en14)].

## Calcium Intakes and Status

A substantial proportion of people in the United States consume less than recommended amounts of calcium. An analysis of 2007–2010 data from the National Health and Nutrition Examination Survey (NHANES) found that 49% of children age 4–18 years and 39% of all individuals age 4 and older consume less than the EAR for calcium from foods and supplements [[17](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en17)].

Average daily intakes of calcium from foods and beverages are 1,083 mg for men age 20 and older and 842 mg for women [[18](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en18)]. For children age 2–19, mean daily intakes of calcium from foods and beverages range from 965 to 1,015 mg [[18](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en18)]. Approximately 22% of men, 32% of women, and 4% to 8% of children take a dietary supplement containing calcium [[18](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en18)]. Average daily calcium intakes from both foods and supplements are 1,156 mg for men, 1,009 mg for women, and 968 to 1,020 mg for children [[18](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en18)].

According to 2009–2012 NHANES data, rates of calcium inadequacy (intakes below the EAR) are higher among non-Hispanic Blacks and non-Hispanic Asians (47%–48%) than among Hispanics (30%) and non-Hispanic Whites (24%) in the United States [[19](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en19)]. Poverty is also associated with a higher risk of inadequacy. NHANES data from 2007 to 2014 show that the risk of inadequate calcium intakes (less than 800 to 1,100 mg) is 11.6% higher among adults age 50 and older in households earning less than $20,000 per year than other households [[20](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en20)].

## Calcium Deficiency

Calcium deficiency can reduce bone strength and lead to osteoporosis, which is characterized by fragile bones and an increased risk of falling [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. Calcium deficiency can also cause rickets in children and other bone disorders in adults, although these disorders are more commonly caused by vitamin D deficiency. In children with rickets, the growth cartilage does not mineralize normally, which can lead to irreversible changes in the skeletal structure [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. Another effect of chronic calcium deficiency is osteomalacia, or defective bone mineralization and bone softening, which can occur in adults and children [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. For rickets and osteomalacia, the requirements for calcium and vitamin D appear to be interrelated in that the lower the serum vitamin D level (measured as 25-hydroxyvitamin D [25(OH)D]), the more calcium is needed to prevent these diseases [[21](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en21)].

Hypocalcemia (serum calcium level less than 8.5 mg/dL [2.12 mmol/L] or an ionized calcium level below 4.61 mg/dL [1.15 mmol/L]) is usually a result of a vitamin D or magnesium deficiency, impaired parathyroid hormone production leading to hypoparathyroidism, impaired bone resorption of calcium, critical illness, or use of certain medications (e.g., bisphosphonates, cisplatin, or proton pump inhibitors) [[22](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en22),[23](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en23)]. Hypocalcemia can be asymptomatic, especially when it is mild or chronic [[23](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en23)]. When signs and symptoms do occur, they can range widely because low serum calcium levels can affect most organs and symptoms [[24](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en24)]. The most common symptom is increased neuromuscular irritability, including perioral numbness, tingling in the hands and feet, and muscle spasms [[23](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en23)]. More severe signs and symptoms can include renal calcification or injury; brain calcification; neurologic symptoms (e.g., depression and bipolar disorder); cataracts; congestive heart failure; paresthesia; seizures; and, in rare cases, coma [[22](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en22),[24](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en24)].

## Groups at Risk of Calcium Inadequacy

The following groups are among those most likely to need extra calcium.

### Postmenopausal women

Menopause leads to bone loss because decreases in estrogen production reduce calcium absorption and increase urinary calcium loss and calcium resorption from bone [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. On average, women lose approximately 1% of their bone mineral density (BMD) per year after menopause [[25](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en25)]. Over time, these changes lead to decreased bone mass and fragile bones [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. About 30% of postmenopausal women in the United States and Europe have osteoporosis, and at least 40% of those with this condition develop at least one fragility fracture (a fracture that occurs after minor trauma, such as a fall from standing height or lower) [[26](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en26)]. The calcium RDA is 1,200 mg for women older than 50 years (vs. 1,000 mg for younger women) to lessen bone loss after menopause [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)].

### Individuals who avoid dairy products

People with lactose intolerance, those with an allergy to milk, and those who avoid eating dairy products (including vegans) have a higher risk of inadequate calcium intakes because dairy products are rich sources of calcium [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1),[27](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en27)]. Options for increasing calcium intakes in individuals with lactose intolerance include consuming lactose-free or reduced-lactose dairy products, which contain the same amounts of calcium as regular dairy products [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1),[3](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en3)]. Those who avoid dairy products because of allergies or for other reasons can obtain calcium from nondairy sources, such as some vegetables (e.g., kale, broccoli, and Chinese cabbage [bok choi]), canned fish with bones, or fortified foods (e.g., fruit juices, breakfast cereals, and tofu) [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. However, these individuals typically need to eat foods fortified with calcium or take supplements to obtain recommended amounts [[28](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en28)].

## Calcium and Health

This section focuses on six health conditions and diseases in which calcium might play a role: bone health in older adults, cancer, cardiovascular disease (CVD), preeclampsia, weight management, and metabolic syndrome.

### Bone health in older adults

Bone is constantly being remodeled. Declining levels of estrogen in women during menopause and for approximately 5 years afterward lead to rates of bone resorption that are higher than rates of bone formation, resulting in a rapid decrease in bone mass [[7](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en7)]. Over time, postmenopausal women can develop osteoporosis, in which bone strength is compromised because of lower BMD and bone quality [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. Age-related bone loss can also occur in men and lead to osteoporosis, but fracture risk tends to increase in older men about 5 to 10 years later than in older women [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. Osteoporosis increases the risk of fractures, especially of the hip, vertebrae, and forearms [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1),[7](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en7)].

FDA has approved a health claim for the use of supplements containing calcium and vitamin D to reduce the risk of osteoporosis [[29](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en29)]. However, not all research supports this claim.

#### Bone mineral density

In spite of the importance of calcium in bone health, observational evidence is mixed on the link between calcium intakes and measures of bone strength in older adults. Support for such a link comes from an analysis of 2001–2006 NHANES cross-sectional data on 2,904 adults age 60 and older (54.6% women) showing an association between higher dietary calcium intakes and greater lumbar spine BMD, but only in women [[30](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en30)]. In contrast, an analysis of baseline data from a randomized trial in Australia in 1,994 women older than 65 years whose average dietary calcium intake was 886 mg/day found no association between quintile of calcium intake and BMD at any site, even after adjustment for such factors as age, physical activity, height, and weight [[31](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en31)]. Results were similar in 698 of the women who were followed for 6 years, even though mean daily intakes of calcium dropped by an average of 40 mg during this period.

Some but not all clinical trials have found that calcium supplementation can improve bone health in older adults. A post-hoc analysis of data from a double-blind, randomized controlled trial (RCT) of 1,000 mg elemental calcium in the form of calcium carbonate and 400 International Units (IU) (10 microgram [mcg]) vitamin D3 daily or placebo in 36,282 women age 50–79 years enrolled in the Women’s Health Initiative (WHI) found that the supplementation did not prevent height loss after a mean follow-up period of 5.9 years [[32](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en32)]. On average, women lost 1.28 mm/year of height in the supplementation group and 1.26 mm/year in the placebo group. However, a 2-year RCT in 500 healthy postmenopausal women showed that daily intakes of 500 ml/day skimmed milk enriched to provide 900 mg calcium and 15 mcg (600 IU) vitamin D led to increased BMD at the femoral neck [[33](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en33)].

Several recent systematic reviews and meta-analyses have found that supplementation with calcium alone or a combination of calcium and vitamin D increases BMD in older adults. For example, a systematic review and meta-analysis included 15 RCTs in postmenopausal women (but did not include the two studies described in the previous paragraph) in 78,206 women, of which 37,412 were in the intervention group and 40,794 were in the control group [[34](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en34)]. Supplementation with both calcium and vitamin D or consumption of dairy products fortified with both nutrients increased total BMD as well as BMD at the lumbar spine, arms, and femoral neck. However, in subgroup analyses, calcium had no effect on femoral neck BMD. Earlier systematic reviews and meta-analyses found a positive relationship between calcium and vitamin D supplementation and increased BMD in older males [[35](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en35)] and between higher calcium intakes from dietary sources or supplements and higher BMD in adults older than 50 [[25](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en25)]. However, whether these BMD increases were clinically significant is not clear.

#### Fractures

As with the evidence on the link between increased calcium intakes and reductions in BMD loss, the findings of research on the use of calcium supplementation to prevent fractures in older adults are mixed.

For the most part, the observational evidence does not show that increasing calcium intakes reduces the risk of fractures and falls in older adults. For example, a longitudinal cohort study of 1,490 women age 42 to 52 years at baseline who were followed for 10–12 years found that fracture risk was not significantly different in calcium supplement users (some of whom also took vitamin D supplements) and nonusers, even though supplement use was associated with less BMD loss throughout the study period [[36](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en36)].

Some clinical trial evidence shows that supplements containing a combination of calcium and vitamin D can reduce the risk of fractures in older adults. For example, a meta-analysis of 8 RCTs in 30,970 adults older than 50 years found that 500 to 1,200 mg/day calcium and 400 to 800 IU/day (10 to 20 mcg/day) vitamin D supplementation for 1 to 7 years reduced the risk of total fractures by 15% and hip fractures by 30% [[37](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en37)]. However, findings were negative in another systematic review and meta-analysis that included 14 RCTs of calcium supplementation and 13 trials comparing calcium and vitamin D supplements with hormone therapy, placebo, or no treatment in participants older than 50 years [[38](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en38)]. The results showed that calcium supplementation alone had no effect on risk of hip fracture, and supplementation with both calcium and vitamin D had no effect on risk of hip fracture, nonvertebral fracture, vertebral fracture, or total fracture. Similarly, a systematic review of 11 RCTs in 51,419 adults age 50 and older found that supplementation with vitamin D and calcium for 2 to 7 years had no impact on risk of total fractures or of hip fractures [[39](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en39)].

The U.S. Preventive Services Task Force (USPSTF) concluded with moderate certainty that daily doses of less than 1,000 mg calcium and less than 400 IU (10 mcg) vitamin D do not prevent fractures in postmenopausal women and that the evidence on larger doses of this combination is inadequate to assess the benefits in this population [[40](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en40)]. The USPSTF also determined the evidence on the benefits of calcium supplementation alone or with vitamin D to be inadequate to assess its effect on preventing fractures in men and premenopausal women.

Additional research is needed before conclusions can be drawn about the use of calcium supplements to improve bone health and prevent fractures in older adults.

### Cancer

Calcium might help reduce the risk of cancer, especially in the colon and rectum [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)]. However, evidence on the relationship between calcium intakes from foods or supplements and different forms of cancer is inconsistent [[4](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en4)].

#### All-cancer incidence and mortality

Most clinical trial evidence does not support a beneficial effect of calcium supplements on cancer incidence. A 4-year study of 1,500 mg calcium and 2,000 IU (50 mcg) vitamin D or placebo daily for 4 years in 2,303 healthy women age 55 years and older showed that supplementation did not reduce the risk of all types of cancer [[41](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en41)]. The large WHI study described above also found no benefit of supplemental calcium and vitamin D on cancer incidence [[42](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en42)]. In addition, a meta-analysis of 10 RCTs that included 10,496 individuals who took supplements containing 500 mg calcium or more (without vitamin D) for a mean of 3.9 years found that calcium supplementation did not change the total cancer risk [[43](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en43)]. However, one large clinical trial did find that calcium supplements reduce cancer risk. In this 4-year trial, by the same investigators as the 4-year trial above, 1,179 women age 55 years or older in Nebraska took 1,400 to 1,500 mg calcium alone; 1,400 to 1,500 mg calcium plus 1,100 IU (27.5 mcg) vitamin D3; or placebo daily. Cancer incidence from all causes was 60% lower in women who took the combination and 47% lower in those who took calcium-only supplements than in the placebo group [[44](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en44)]. Some scientists have questioned these findings because of the lack of statistical power (the studies were designed to detect differences in bone health measures, not cancer incidence), details from the investigators on the study sample, and randomization procedures [[45](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en45),[46](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en46)].

Observational evidence does not support an association between higher calcium intakes and a lower risk of cancer mortality. An analysis of data on 132,823 participants in the Cancer Prevention Study II Nutrition Cohort, who were followed for an average of 17.5 years, found no association between total dietary and supplemental calcium intakes and risk of cancer-related death or death from lung, colorectal, breast, or prostate cancer in men or women [[47](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en47)]. A systematic review and meta-analysis of 22 observational studies in 2,346,368 participants age 8 and older followed for 4.6 to 28 years also found no association between total dietary and supplemental calcium intake and cancer mortality [[48](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en48)].

Clinical trials have also not shown that supplemental calcium alone or combined with vitamin D has an impact on risk of mortality from all cancers. An RCT in 5,292 adults age 70 years or older (85% women) in the United Kingdom compared the effects of 1,000 mg calcium, 8,000 IU (200 mcg) vitamin D3, both, or placebo for 24 to 62 months [[49](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en49)]. Rates of cancer incidence and cancer mortality did not differ between those who did and those who did not receive calcium supplements. In the WHI trial, 36,282 postmenopausal women were randomly assigned to daily supplementation with a combination of 1,000 mg calcium and 400 IU (10 mcg) vitamin D3 or placebo [[42](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en42)]. After an average of 7 years, risk of cancer mortality did not differ between groups. The meta-analysis of 10 RCTs that included 10,496 individuals described above found no impact of calcium supplementation on cancer mortality rates [[43](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en43)].

#### Colorectal cancer

A substantial body of evidence has addressed the role of calcium in preventing colorectal cancer or its precursor, adenomas.

Much but not all of the observational evidence supports a link between higher calcium intakes and lower risk of colorectal cancer. A cohort study in 77,712 adults found that over a mean of 7.8 years, the highest total intake of dietary and supplemental calcium (median of 1,999 mg/day) was associated with a 26% lower risk of colon cancer than the lowest quintile (587 mg/day) but had no association with risk of rectal cancer [[50](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en50)]. In a dose-response meta-analysis of 15 prospective cohort studies in 1,415,597 participants (mean total dietary and supplemental calcium intake 250 to 1,900 mg/day) followed for 3.3 to 16 years, risk of colorectal cancer dropped by 8% with each 300 mg/day increase in total calcium intake [[51](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en51)]. Findings were similar for dietary intakes of calcium in two other meta-analyses [[52](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en52),[53](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en53)].

In spite of the observational evidence supporting an association between higher calcium intakes and lower colorectal cancer risk, clinical trials investigating calcium supplements for prevention of colorectal cancer or adenomas have had mixed results. A 2013 follow-up study by Cauley and colleagues evaluated outcomes 4.9 years after completion of the 7-year WHI trial of 1,000 mg/day calcium plus 400 IU (10 mcg)/day vitamin D3 or placebo in 36,282 postmenopausal women [[54](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en54)]. Colorectal cancer rates did not differ between groups. Similarly, in a follow-up study an average of 55 months after administration of 1,200 mg/day calcium, 1,000 IU (25 mcg)/day vitamin D3, or both for 3 to 5 years in 1,121 participants, supplements had no effect on risk of recurrent adenomas [[55](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en55)]. However, a systematic review and meta-analysis of four RCTs (not including the 2013 study by Cauley and colleagues) found that daily supplementation with 1,200 to 2,000 mg elemental calcium for 36 to 60 months reduced the likelihood of recurrent adenomas by 11%, although the supplements had no effect on risk of advanced adenomas [[56](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en56)].

#### Other cancers

Several observational studies have shown that the risk of prostate cancer might be higher with higher calcium intakes, but possibly only when the calcium comes from dairy foods. In an analysis of data from 2,776 men who participated in the French SU.VI.MAX (Supplementation en Vitamines et Minéraux Antioxydants) prospective study and were followed for an average of 7.7 years, prostate cancer risk was higher with higher calcium intakes [[57](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en57)]. The risk was 2.4 times higher in men in the highest quartile of intake (more than 1,081 mg/day) than those with the lowest quartile (less than 725 mg/day). However, in analyses of results for various sources of calcium, only calcium from dairy foods was significantly associated with prostate cancer risk (2.9 times higher in men with intakes greater than 696 mg/day than in those with intakes less than 354 mg/day); calcium intakes from nondairy sources were not significantly associated with prostate cancer risk. In a systematic review and meta-analysis of nine cohort studies in 750,275 men, the risk of prostate cancer was 2% higher for each 400 mg/day increment in total dietary and supplemental calcium intake, but nondairy and supplemental calcium intakes were not associated with prostate cancer risk [[58](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en58)].

A meta-analysis included 15 epidemiological studies of calcium intake and ovarian cancer risk in 493,415 women who developed 7,453 cases of ovarian cancer [[59](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en59)]. In this meta-analysis, ovarian cancer risk was 20% lower in participants in the highest category of dietary calcium intakes (more than 820–1,500 mg/day, depending on the study) than the lowest intake category (less than 362–800 mg/day, depending on the study). However, the difference in risk was not statistically significant when both dietary and supplemental calcium intakes were considered.

For breast cancer, observational studies have had mixed findings on whether higher calcium intakes are associated with a lower risk. A meta-analysis of 11 prospective cohort studies in 872,895 women who developed 26,606 cases of breast cancer over 7 to 25 years found that women with the highest calcium intakes had an 8% lower risk of breast cancer [[60](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en60)]. However, the WHI (described above) found similar incidence rates of invasive breast cancer in the supplement and placebo groups [[61](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en61)].

#### Conclusion

Additional well-designed randomized trials are needed to determine whether dietary or supplemental calcium intakes increase, decrease, or have no effect on risk of cancer in general or of specific types of cancer, or on cancer mortality.

### Cardiovascular disease

Calcium binds fatty acids, so it can reduce lipid absorption and might therefore lower CVD risk [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1),[4](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en4)]. However, the findings from research on the role of dietary calcium and calcium supplements in reducing CVD have been mixed, and some evidence indicates that calcium supplements might even increase CVD risk.

Several large observational studies have shown an association between lower calcium intakes and higher risk of hypertension, stroke, and atherosclerosis. For example, an analysis of 1999–2010 NHANES data from 14,408 adults (mean age 54 years) with obesity found that calcium intakes were 10% lower in adults with obesity and hypertension than in those without hypertension [[62](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en62)]. This association was strongest in women, adults age 20–44 years, those who did not have diabetes, and especially women age 20–44 years. A prospective cohort study that followed 41,514 adults age 40 to 69 years in Australia for 13 years found a 25% lower rate of stroke in adults in the highest calcium intake quartile (mean of 1,076 mg/day) than in the lowest quartile (mean of 641 mg/day) [[63](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en63)]. However, the study found no association between calcium intakes and risk of CVD mortality or myocardial infarction. The risk of atherosclerosis over 10 years in a study of 5,448 adults age 45–84 years was 27% lower in the highest quintile of calcium intake (mean of 2,157 mg/day) than in the lowest quintile (mean of 313 mg/day) [[64](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en64)]. Furthermore, a systematic review and meta-analysis that included 27 observational studies found no consistent dose-response relationships between total, dietary, or supplemental calcium intakes and CVD mortality [[65](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en65)]. Evidence on dose-response relationships between calcium intakes and risk of stroke or stroke mortality was inconsistent.

A diet containing more calcium than the typical U.S. diet because of added low-fat or nonfat dairy products lowered systolic blood pressure by an average of 5.5 mmHg and diastolic blood pressure by 3.0 mmHg [[66](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en66)]. However, this Dietary Approaches to Stop Hypertension (DASH) diet also increases intakes of other nutrients, such as potassium and magnesium, that are associated with reductions in blood pressure, so any independent contribution of calcium cannot be determined.

Some clinical trials have shown that calcium supplements are associated with decreased hypertension risk or decreased cholesterol levels, but others have had more mixed findings. A Cochrane Review of 16 trials in 3,048 adults with a median follow-up period of 3.5 months found that calcium supplementation (typically 1,000 to 2,000 mg/day) reduced systolic blood pressure by 1.43 mmHg and diastolic blood pressure by 0.98 mmHg [[67](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en67)]. Effects were greatest in adults younger than 35 years and with doses higher than 1,500 mg/day calcium. A meta-analysis of 23 RCTs in 4,071 participants showed that calcium supplements providing 162 to 2,000 mg/day (combined with vitamin D in 10 RCTs) for 2 weeks to 5 years was associated with low-density lipoprotein cholesterol levels that were 4.6 mg/dL lower and high-density lipoprotein cholesterol levels that were 1.9 mg/dL higher [[68](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en68)].

Findings were mixed in two analyses of data from the WHI. One analysis of results from 35,983 women age 50 to 79 years randomly assigned to 1,000 mg/day calcium and 400 IU (10 mcg)/day vitamin D supplements or placebo for 10 years found no reduction in risk of heart failure [[69](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en69)]. However, the calcium and vitamin D supplements were associated with 5% lower heart failure risk in participants who had no pre-existing heart failure risk factors (coronary heart disease, diabetes, or hypertension). In another secondary analysis of data on 16,801 WHI participants, the supplements had no association with atrial fibrillation risk [[70](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en70)]. Similarly, an evidence report and systematic review conducted for the USPSTF that included 11 RCTs of vitamin D, calcium, or both for 2 to 7 years in 51,419 adults age 50 years and older found that supplementation with vitamin D alone or combined with calcium had no effect on CVD incidence [[39](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en39)].

In contrast, several prospective cohort studies and RCTs have shown that calcium supplements increase the risk of CVD. A meta-analysis of 14 RCTs (including one study that administered supplements providing 20 mcg [800 IU] vitamin D per day) in 28,935 healthy postmenopausal women found that calcium supplements providing 500 to 2,000 mg/day calcium for 1 to 7 years increased CVD risk by 15% and coronary heart disease risk by 16% [[71](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en71)]. In addition, when 132,823 adults (mean age 63 years) were followed for an average of 17.5 years, the risk of CVD mortality was 22% higher in men with calcium supplement intakes of 1,000 mg/day or more than in those not taking calcium supplements [[47](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en47)]. However, in women, the CVD mortality rate was 16% lower with supplemental calcium intakes of 1,000 mg/day than with no supplemental calcium intakes.

Other studies have found no association between calcium supplements and CVD risk or CVD outcomes. After 24 years of follow-up of 74,245 women age 30 to 55 years at baseline who participated in the Nurses’ Health Study, women taking more than 1,000 mg/day calcium supplements did not have a higher risk of CVD than those taking no supplemental calcium [[72](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en72)].

An expert panel convened by the National Osteoporosis Foundation and American Society for Preventive Cardiology determined, on the basis of moderate-quality evidence, that calcium intakes with or without vitamin D from foods or supplements neither increase nor decrease the risk of CVD or CVD mortality [[73](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en73)]. The societies therefore concluded that calcium intakes that do not exceed the UL are safe “from a cardiovascular standpoint.”

### Preeclampsia

Preeclampsia is defined as hypertension and proteinuria or thrombocytopenia during pregnancy, usually after 20 weeks’ gestation [[74](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en74)]. It is a leading cause of maternal and neonatal morbidity and mortality that affects about 4% of pregnancies in the United States [[75](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en75)].

Calcium supplementation during pregnancy might reduce the risk of preeclampsia, but the benefits might apply only to women with inadequate calcium intakes, and much of this evidence comes from studies with methodological weaknesses [[76](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en76),[77](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en77)].

A Cochrane Review included 27 RCTs of calcium supplements during pregnancy in 18,064 women to prevent hypertensive disorders and related problems [[78](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en78)]. In the 13 studies—none of which administered vitamin D supplements—that evaluated high doses (at least 1,000 mg/day calcium) in 15,730 women, supplementation reduced the risk of high blood pressure by 35% and, in women with low dietary calcium intakes (less than 1,000 mg/day; 10 trials in 10,678 women), the risk of preeclampsia by 55%. However, the quality of this evidence was low. In 12 trials in 2,334 women, doses of less than 1,000 mg/day (usually 500 mg/day) reduced the risk of high blood pressure by 47% and of preeclampsia by 62%. However, most of these studies recruited women at high risk of preeclampsia and had a high risk of bias. An earlier systematic review and meta-analysis of 10 RCTs in 24,787 women also found that calcium supplementation (1,500 to 2,000 mg/day) reduced the risk of preeclampsia by 38% and, in women at increased risk of any hypertensive disorder of pregnancy, by 58% [[79](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en79)]. However, when the analysis was restricted to trials with 4,000 or more women, the effect was no longer statistically significant. An RCT in 1,355 women in Argentina, South Africa, and Zimbabwe also found that 500 mg/day calcium supplementation starting before conception made no difference in the risk of preeclampsia [[80](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en80),[81](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en81)].

Several professional organizations recommend calcium supplements during pregnancy for women with low calcium intakes to reduce the risk of preeclampsia. For example, the American College of Obstetrics and Gynecology states that daily supplementation with 1,500–2,000 mg calcium might reduce the severity of preeclampsia in pregnant women who have calcium intakes of less than 600 mg/day [[76](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en76)]. The World Health Organization recommends 1,500–2,000 mg/day calcium for pregnant women with low dietary calcium intakes to reduce preeclampsia risk [[82](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en82)]. The Canadian Hypertensive Disorders of Pregnancy Working Group [[83](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en83)], the International Society for the Study of Hypertension in Pregnancy [[84](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en84)], and the Society of Obstetric Medicine of Australia and New Zealand [[85](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en85)] have similar recommendations.

### Weight management

Observational and clinical trial evidence linking higher calcium intakes from dairy products or supplements to lower body weight or less weight gain over time is mixed.

An observational study found an association between higher calcium intakes and lower prevalence of overweight or obesity in 6,696 children (51% male, mean age 6 years) in eight European countries, of whom 2,744 were re-examined 6 years later [[86](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en86)]. The prevalence of overweight or obesity at 6-year follow-up was lower in boys (16%) and girls (18%) in the highest tertile of calcium intake (664 mg/1,000 kcal for boys and 667 mg/1,000 kcal for girls) than in boys (26%) and girls (25%) in the lowest tertile (249 mg/1,000 kcal for both boys and girls). In contrast, a longitudinal study in 2,159 participants in Portugal evaluated at ages 13 and 21 years found no association between total dietary and supplemental calcium intake at age 13 and body mass index (BMI) at age 21 after the analysis was adjusted for energy intake [[87](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en87)]. The study also found no associations between consumption of dairy foods (milk, yogurt, and cheese) at age 13 and BMI at age 21.

Clinical trials and meta-analyses of RCTs assessing the impact of calcium supplements or increased intakes of calcium from dairy products on prevention of weight gain or promotion of fat loss or weight loss have had mixed results [[88-92](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en88)]. For example, postmenopausal women who took 1,000 mg calcium and 400 IU (10 mcg) vitamin D daily for 3 years in the WHI whose daily intakes were less than 1,200 mg calcium at baseline were 11% less likely to gain 1 kg of weight or more than those who took placebo during this period [[90](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en90)]. A systematic review and meta-analysis of 41 RCTs that examined the effect of dairy foods or calcium supplements (at least 300 mg/day) in 4,802 adults found that higher calcium intakes from dairy foods had no impact on body weight or body fat, although they did reduce body fat when combined with an energy-restricted diet [[91](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en91)]. In addition, calcium supplements had no effect on body weight or body fat.

For additional information on calcium and weight management, see the health professional fact sheet on [weight loss](https://ods.od.nih.gov/factsheets/WeightLoss-HealthProfessional/#h3).

### Metabolic syndrome

Metabolic syndrome is a set of at least three risk factors for heart disease, stroke, and diabetes—large waistline, high triglyceride level, low high-density lipoprotein cholesterol level, high blood pressure, and high fasting blood sugar level. Some observational evidence links higher calcium intakes with lower risk of metabolic syndrome.

An analysis of 2001–2010 NHANES data on 9,148 adults found that women in the highest quintile (at least 1,172 mg/day) of calcium intake, based on 24-hour recall, had a 27% lower risk of metabolic syndrome than those in the lowest quintile (less than 547 mg/day) [[93](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en93)]. Furthermore, women who met the RDA for calcium for adults (1,000 to 1,200 mg/day, depending on age) had an 18% lower risk of metabolic syndrome, but the association was not statistically significant in men who met the RDA for calcium. In a meta-analysis of eight cross-sectional studies and two prospective cohort studies in 63,017 participants age 20 years and older, 14,906 participants developed metabolic syndrome [[94](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en94)]. For each 300 mg/day increase in dietary calcium intake, risk of metabolic syndrome dropped by 7%. Subgroup analyses suggested that the inverse association between dietary calcium intakes and metabolic syndrome risk was stronger in women than men.

Clinical trial evidence on the link between calcium and metabolic syndrome is very limited. In one placebo-controlled clinical trial in Iran in 66 adults who were overweight and had type 2 diabetes and coronary heart disease, supplements of 5 mcg (200 IU) vitamin D, 90 mcg vitamin K, and 500 mg calcium for 12 weeks significantly reduced maximum levels of left carotid intima media thickness and improved metabolic status (including improvements in insulin resistance, insulin concentrations, beta-cell function, and quantitative insulin sensitivity check index) [[95](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en95)].

More evidence, including from well-designed clinical trials, is needed to determine whether higher intakes of calcium can reduce the risk of metabolic syndrome.

## Health Risks from Excessive Calcium

Hypercalcemia (serum levels greater than 10.5 mg/dL [2.63 mmol/L]) and hypercalciuria (urinary calcium levels higher than 250 mg/day in women and 275 mg/day in men) are rare in healthy people and usually result from cancer, primary hyperparathyroidism, and other conditions [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1),[4](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en4)]. Hypercalcemia and hypercalciuria can cause poor muscle tone, renal insufficiency, hypophosphatemia, constipation, nausea, weight loss, fatigue, polyuria, heart arrhythmias, and a higher risk of CVD mortality [[1](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1),[4](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en4),[48](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en48)].

High calcium intakes might also increase the risk of CVD (see section on CVD in Calcium and Health section above) [[39](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en39),[62](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en62),[67](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en67),[69](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en69),[70](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en70)] and prostate cancer (see Other Cancers in Calcium and Health section above for more details) [[57](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en57),[58](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en58)], although not all studies confirm these findings.

The ULs for calcium established by the FNB are listed in Table 3. They are based on observational evidence from the WHI showing a link between higher intakes of supplemental calcium (1,000 mg/day for 7 years) and a greater risk of kidney stones [[96](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en96),[97](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en97)]. However, two subsequent systematic reviews of the evidence from 10 studies in more than 8,000 adults with osteoporosis who took 120 to 1,500 mg supplemental calcium daily for 3 days to 3 years [[98](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en98)] and 11 RCTs in 51,419 adults 50 years and older who took 1,000 to 1,600 mg calcium with or without vitamin D for 2 to 7 years [[39](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en39)] found no such association.

| **Table 3: Tolerable Upper Intake Levels (ULs) for Calcium [**[**1**](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en1)**]** | | | | |
| --- | --- | --- | --- | --- |
| **Age** | **Male** | **Female** | **Pregnant** | **Lactating** |
| 0–6 months | 1,000 mg | 1,000 mg |  |  |
| 7–12 months | 1,500 mg | 1,500 mg |  |  |
| 1–8 years | 2,500 mg | 2,500 mg |  |  |
| 9–18 years | 3,000 mg | 3,000 mg | 3,000 mg | 3,000 mg |
|  |  |  |  |  |
| 19–50 years | 2,500 mg | 2,500 mg | 2,500 mg | 2,500 mg |
| 51+ years | 2,000 mg | 2,000 mg |  |  |

## Interactions with Medications

Calcium has the potential to interact with certain medications, and several types of medications might adversely affect calcium levels. A few examples are provided below. Individuals taking these and other medications on a regular basis should discuss their calcium status with their health care providers.

### Dolutegravir

Dolutegravir (Dovato, Tivicay) is an HIV integrase inhibitor used in adults and children. Concomitant use of calcium supplements and dolutegravir can reduce blood levels of dolutegravir substantially, apparently through chelation [[99](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en99),[100](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en100)]. The labels approved by the FDA for dolutegravir advise patients to take dolutegravir 2 hours before or 6 hours after taking calcium supplements [[101](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en101),[102](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en102)].

### Levothyroxine

Calcium carbonate supplements can interfere with the absorption of levothyroxine (Synthroid, Levoxyl, and others), a thyroid hormone used to treat hypothyroidism and thyroid cancer [[103-105](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en103)]. The FDA-approved label for this medication instructs patients taking calcium carbonate supplements to avoid taking levothyroxine within 4 hours of taking the supplement [[106](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en106)].

### Lithium

Long-term use of lithium (Eskalith, Lithobid), a treatment for bipolar disorder, can lead to hypercalcemia, and use of both lithium and calcium supplements could increase this risk [[107](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en107)].

### Quinolone antibiotics

Simultaneous use of calcium supplements and quinolone antibiotics—such as ciprofloxacin (Cipro), gemifloxacin (Factive), and moxifloxacin (Avelox)—can reduce the absorption of quinolones [[108](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en108),[109](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en109)]. Taking the antibiotic 2 hours before or 2 hours after calcium supplements prevents this effect [[108](https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/#en108)].

## Calcium and Healthful Diets

The federal government’s 2020–2025 Dietary Guidelines for Americans notes that “Because foods provide an array of nutrients and other components that have benefits for health, nutritional needs should be met primarily through foods. … In some cases, fortified foods and dietary supplements are useful when it is not possible otherwise to meet needs for one or more nutrients (e.g., during specific life stages such as pregnancy).

For more information about building a healthy dietary pattern, refer to the [*Dietary Guidelines for Americans*](https://www.dietaryguidelines.gov/)*[external link disclaimer](https://ods.od.nih.gov/About/exit_disclaimer.aspx)* and the USDA’s [MyPlate](https://www.myplate.gov/)[external link disclaimer](https://ods.od.nih.gov/About/exit_disclaimer.aspx).

The Dietary Guidelines for Americans describes a healthy eating pattern as one that

* Includes a variety of vegetables, fruits, whole grains, fat-free or low-fat milk and milk products, and oils.
  + Many dairy products, such as milk, cheese, and yogurt, are rich sources of calcium. Some vegetables provide significant amounts of calcium, as do some fortified cereals and juices.
* Includes a variety of protein foods, including seafood, lean meats and poultry, eggs, legumes (beans and peas), nuts, seeds, and soy products.
  + Tofu made with calcium salts is a good source of calcium (check the label), as are canned sardines and canned salmon with edible bones.
* Limits foods and beverages higher in added sugars, saturated fat, and sodium.
* Limits alcoholic beverages.
* Stays within your daily calorie needs.

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## Disclaimer

This fact sheet by the National Institutes of Health (NIH) Office of Dietary Supplements (ODS) provides information that should not take the place of medical advice. We encourage you to talk to your health care providers (doctor, registered dietitian, pharmacist, etc.) about your interest in, questions about, or use of dietary supplements and what may be best for your overall health. Any mention in this publication of a specific product or service, or recommendation from an organization or professional society, does not represent an endorsement by ODS of that product, service, or expert advice.

# Calendula

## What is it?

Calendula (Calendula officinalis) is a plant known as pot marigold. It is not the same as ornamental marigolds of the Tagetes genus grown in vegetable gardens.  
  
Calendula is native to Asia and southern Europe and has been traditionally used in Ayurvedic and Unani systems of medicine. The chemicals in calendula might help new tissue grow in wounds and decrease swelling in the mouth and throat.  
  
Calendula flower is commonly used for wounds, rashes, infections, inflammation, and many other conditions. But there's no strong evidence to support the use of calendula for any purpose.

## How effective is it?

There is interest in using calendula for a number of purposes, but there isn't enough reliable information to say whether it might be helpful.

## Is it safe?

**When taken by mouth**: Preparations of calendula flower are likely safe for most people.  
  
**When applied to the skin**: Preparations of calendula flower are likely safe for most people.

#### Special precautions & warnings:

**Pregnancy**: Don't take calendula by mouth if you are pregnant. It is likely unsafe. There is a concern that it might cause a miscarriage. It's best to avoid topical use as well until more is known.  
  
**Breast-feeding**: There isn't enough reliable information to know if calendula is safe to use when breast-feeding. Stay on the safe side and avoid use.  
  
**Allergy to ragweed and related plants**: Calendula may cause an allergic reaction in people who are sensitive to the Asteraceae/Compositae family. Members of this family include ragweed, chrysanthemums, marigolds, daisies, and many others. If you have allergies, be sure to check with your healthcare provider before taking calendula.

## Are there interactions with medications?

**Moderate**

**Be cautious with this combination.**

**Sedative medications (CNS depressants)**

Calendula might cause sleepiness and slowed breathing. Some medications, called sedatives, can also cause sleepiness and slowed breathing. Taking calendula with sedative medications might cause breathing problems and/or too much sleepiness.

## Are there interactions with herbs and supplements?

There are no known interactions with herbs and supplements.

## Are there interactions with foods?

There are no known interactions with foods.

## How is it typically used?

There isn't enough reliable information to know what an appropriate dose of calendula might be. Keep in mind that natural products are not always necessarily safe and dosages can be important. Be sure to follow relevant directions on product labels and consult a healthcare professional before using.

## Other names

Caléndula, Calendula officinalis, Calendule, Common Marigold, English Garden Marigold, English Marigold, Fleur de Calendule, Fleur de Tous les Jours, Fleur de Tous les Mois, Garden Marigold, Gold-Bloom, Holligold, Marigold, Marybud, Pot Marigold, Souci des Champs, Souci des Jardins, Souci des Vignes, Souci Officinal, Zergul.

## Methodology

To learn more about how this article was written, please see the *Natural Medicines Comprehensive Database* [methodology](https://medlineplus.gov/druginfo/natural/methodology.html).

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# Vitamin D

## Introduction

Vitamin D (also referred to as calciferol) is a fat-soluble vitamin that is naturally present in a few foods, added to others, and available as a dietary supplement. It is also produced endogenously when ultraviolet (UV) rays from sunlight strike the skin and trigger vitamin D synthesis.

Vitamin D obtained from sun exposure, foods, and supplements is biologically inert and must undergo two hydroxylations in the body for activation. The first hydroxylation, which occurs in the liver, converts vitamin D to 25-hydroxyvitamin D [25(OH)D], also known as calcidiol. The second hydroxylation occurs primarily in the kidney and forms the physiologically active 1,25-dihydroxyvitamin D [1,25(OH)2D], also known as calcitriol [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)].

Vitamin D promotes calcium absorption in the gut and maintains adequate serum calcium and phosphate concentrations to enable normal bone mineralization and to prevent hypocalcemic tetany (involuntary contraction of muscles, leading to cramps and spasms). It is also needed for bone growth and bone remodeling by osteoblasts and osteoclasts [[1-3](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. Without sufficient vitamin D, bones can become thin, brittle, or misshapen. Vitamin D sufficiency prevents rickets in children and osteomalacia in adults. Together with calcium, vitamin D also helps protect older adults from osteoporosis.

Vitamin D has other roles in the body, including reduction of inflammation as well as modulation of such processes as cell growth, neuromuscular and immune function, and glucose metabolism [[1-3](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. Many genes encoding proteins that regulate cell proliferation, differentiation, and apoptosis are modulated in part by vitamin D. Many tissues have vitamin D receptors, and some convert 25(OH)D to 1,25(OH)2D.

In foods and dietary supplements, vitamin D has two main forms, D2 (ergocalciferol) and D3 (cholecalciferol), that differ chemically only in their side-chain structures. Both forms are well absorbed in the small intestine. Absorption occurs by simple passive diffusion and by a mechanism that involves intestinal membrane carrier proteins [[4](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en4)]. The concurrent presence of fat in the gut enhances vitamin D absorption, but some vitamin D is absorbed even without dietary fat. Neither aging nor obesity alters vitamin D absorption from the gut [[4](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en4)].

Serum concentration of 25(OH)D is currently the main indicator of vitamin D status. It reflects vitamin D produced endogenously and that obtained from foods and supplements [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. In serum, 25(OH)D has a fairly long circulating half-life of 15 days [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. Serum concentrations of 25(OH)D are reported in both nanomoles per liter (nmol/L) and nanograms per milliliter (ng/mL). One nmol/L is equal to 0.4 ng/mL, and 1 ng/mL is equal to 2.5 nmol/L.

Assessing vitamin D status by measuring serum 25(OH)D concentrations is complicated by the considerable variability of the available assays (the two most common ones involve antibodies or chromatography) used by laboratories that conduct the analyses [[5](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en5),[6](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en6)]. As a result, a finding can be falsely low or falsely high, depending on the assay used and the laboratory. The international Vitamin D Standardization Program has developed procedures for standardizing the laboratory measurement of 25(OH)D to improve clinical and public health practice [[5](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en5),[7-10](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en7)].

In contrast to 25(OH)D, circulating 1,25(OH)2D is generally not a good indicator of vitamin D status because it has a short half-life measured in hours, and serum levels are tightly regulated by parathyroid hormone, calcium, and phosphate [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. Levels of 1,25(OH)2D do not typically decrease until vitamin D deficiency is severe [[2](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en2)].

### Serum concentrations of 25(OH)D and health

Although 25(OH)D functions as a biomarker of exposure, the extent to which 25(OH)D levels also serve as a biomarker of effect on the body (i.e., relating to health status or outcomes) is not clear [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1),[3](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en3)].

Researchers have not definitively identified serum concentrations of 25(OH)D associated with deficiency (e.g., rickets), adequacy for bone health, and overall health. After reviewing data on vitamin D needs, an expert committee of the Food and Nutrition Board (FNB) at the National Academies of Sciences, Engineering, and Medicine (NASEM) concluded that people are at risk of vitamin D deficiency at serum 25(OH)D concentrations less than 30 nmol/L (12 ng/mL; see Table 1 for definitions of deficiency and inadequacy) [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. Some people are potentially at risk of inadequacy at 30 to 50 nmol/L (12–20 ng/mL). Levels of 50 nmol/L (20 ng/mL) or more are sufficient for most people. In contrast, the Endocrine Society stated that, for clinical practice, a serum 25(OH)D concentration of more than 75 nmol/L (30 ng/mL) is necessary to maximize the effect of vitamin D on calcium, bone, and muscle metabolism [[11](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en11),[12](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en12)]. The FNB committee also noted that serum concentrations greater than 125 nmol/L (50 ng/mL) can be associated with adverse effects [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)] (Table 1).

| **Table 1: Serum 25-Hydroxyvitamin D [25(OH)D] Concentrations and Health [**[**1**](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)**]** | | |
| --- | --- | --- |
| **nmol/L\*** | **ng/mL\*** | **Health status** |
| <30 | <12 | Associated with vitamin D deficiency, which can lead to rickets in infants and children and osteomalacia in adults |
| 30 to <50 | 12 to <20 | Generally considered inadequate for bone and overall health in healthy individuals |
| ≥50 | ≥20 | Generally considered adequate for bone and overall health in healthy individuals |
| >125 | >50 | Linked to potential adverse effects, particularly at >150 nmol/L (>60 ng/mL) |

\*Serum concentrations of 25(OH)D are reported in both nanomoles per liter (nmol/L) and nanograms per milliliter (ng/mL). One nmol/L = 0.4 ng/mL, and 1 ng/mL = 2.5 nmol/L.

Optimal serum concentrations of 25(OH)D for bone and general health have not been established because they are likely to vary by stage of life, by race and ethnicity, and with each physiological measure used [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1),[13](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en13),[14](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en14)]. In addition, although 25(OH)D levels rise in response to increased vitamin D intake, the relationship is nonlinear [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. The amount of increase varies, for example, by baseline serum levels and duration of supplementation.

## Recommended Intakes

Intake recommendations for vitamin D and other nutrients are provided in the Dietary Reference Intakes (DRIs) developed by expert committees of NASEM [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. DRI is the general term for a set of reference values used for planning and assessing nutrient intakes of healthy people. These values, which vary by age and sex, include the following:

* Recommended Dietary Allowance (RDA): Average daily level of intake sufficient to meet the nutrient requirements of nearly all (97%–98%) healthy individuals; often used to plan nutritionally adequate diets for individuals
* Adequate Intake (AI): Intake at this level is assumed to ensure nutritional adequacy; established when evidence is insufficient to develop an RDA
* Estimated Average Requirement (EAR): Average daily level of intake estimated to meet the requirements of 50% of healthy individuals; usually used to assess the nutrient intakes of groups of people and to plan nutritionally adequate diets for them; can also be used to assess the nutrient intakes of individuals
* Tolerable Upper Intake Level (UL): Maximum daily intake unlikely to cause adverse health effects

An FNB committee established RDAs for vitamin D to indicate daily intakes sufficient to maintain bone health and normal calcium metabolism in healthy people. RDAs for vitamin D are listed in both micrograms (mcg) and International Units (IU); 1 mcg vitamin D is equal to 40 IU (Table 2). Even though sunlight is a major source of vitamin D for some people, the FNB based the vitamin D RDAs on the assumption that people receive minimal sun exposure [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. For infants, the FNB committee developed AIs based on the amount of vitamin D that maintains serum 25(OH)D levels above 20 ng/mL (50 nmol/L) and supports bone development.

| **Table 2: Recommended Dietary Allowances (RDAs) for Vitamin D [**[**1**](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)**]** | | | | |
| --- | --- | --- | --- | --- |
| **Age** | **Male** | **Female** | **Pregnancy** | **Lactation** |
| 0-12 months\* | 10 mcg (400 IU) | 10 mcg (400 IU) |  |  |
| 1–13 years | 15 mcg (600 IU) | 15 mcg (600 IU) |  |  |
| 14–18 years | 15 mcg (600 IU) | 15 mcg (600 IU) | 15 mcg (600 IU) | 15 mcg (600 IU) |
| 19–50 years | 15 mcg (600 IU) | 15 mcg (600 IU) | 15 mcg (600 IU) | 15 mcg (600 IU) |
| 51–70 years | 15 mcg (600 IU) | 15 mcg (600 IU) |  |  |
| >70 years | 20 mcg (800 IU) | 20 mcg (800 IU) |  |  |

\*Adequate Intake (AI)

Many other countries around the world and some professional societies have somewhat different guidelines for vitamin D intakes [[15](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en15)]. These differences are a result of an incomplete understanding of the biology and clinical implications of vitamin D, different purposes for the guidelines (e.g., for public health in a healthy population or for clinical practice), and/or the use in some guidelines of observational studies in addition to randomized clinical trials to establish recommendations [[9](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en9),[15](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en15)]. The Endocrine Society states, for example, that to maintain serum 25(OH)D levels above 75 nmol/L (30 ng/mL), adults might need at least 37.5 to 50 mcg (1,500–2,000 IU)/day of supplemental vitamin D, and children and adolescents might need at least 25 mcg (1,000 IU)/day [[11](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en11)]. In contrast, the United Kingdom government recommends intakes of 10 mcg (400 IU)/day for its citizens age 4 years and older [[16](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en16)].

## Sources of Vitamin D

### Food

Few foods naturally contain vitamin D. The flesh of fatty fish (such as trout, salmon, tuna, and mackerel) and fish liver oils are among the best sources [[17](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en17),[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. An animal’s diet affects the amount of vitamin D in its tissues. Beef liver, egg yolks, and cheese have small amounts of vitamin D, primarily in the form of vitamin D3 and its metabolite 25(OH)D3. Mushrooms provide variable amounts of vitamin D2 [[17](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en17)]. Some mushrooms available on the market have been treated with UV light to increase their levels of vitamin D2. In addition, the Food and Drug Administration (FDA) has approved UV-treated mushroom powder as a food additive for use as a source of vitamin D2 in food products [[18](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en18)]. Very limited evidence suggests no substantial differences in the bioavailability of vitamin D from various foods [[19](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en19)].

Animal-based foods typically provide some vitamin D in the form of 25(OH)D in addition to vitamin D3. The impact of this form on vitamin D status is an emerging area of research. Studies show that 25(OH)D appears to be approximately five times more potent than the parent vitamin for raising serum 25(OH)D concentrations [[17](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en17),[20](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en20),[21](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en21)]. One study found that when the 25(OH)D content of beef, pork, chicken, turkey, and eggs is taken into account, the total amount of vitamin D in the food is 2 to 18 times higher than the amount in the parent vitamin alone, depending on the food [[20](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en20)].

Fortified foods provide most of the vitamin D in American diets [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1),[22](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en22)]. For example, almost all of the U.S. milk supply is voluntarily fortified with about 3 mcg/cup (120 IU), usually in the form of vitamin D3 [[23](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en23)]. In Canada, milk must be fortified with 0.88–1.0 mcg/100 mL (35–40 IU), and the required amount for margarine is at least 13.25 mcg/100 g (530 IU). Other dairy products made from milk, such as cheese and ice cream, are not usually fortified in the United States or Canada. Plant milk alternatives (such as beverages made from soy, almond, or oats) are often fortified with similar amounts of vitamin D to those in fortified cow’s milk (about 3 mcg [120 IU]/cup); the Nutrition Facts label lists the actual amount [[24](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en24)]. Ready-to-eat breakfast cereals often contain added vitamin D, as do some brands of orange juice, yogurt, margarine, and other food products.

The United States mandates the fortification of infant formula with 1–2.5 mcg/100 kcal (40–100 IU) vitamin D; 1–2 mcg/100 kcal (40–80 IU) is the required amount in Canada [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)].

A variety of foods and their vitamin D levels per serving are listed in Table 3.

| **Table 3: Vitamin D Content of Selected Foods [**[**25**](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en25)**]** | | | |
| --- | --- | --- | --- |
| **Food** | **Micrograms (mcg) per serving** | **International Units (IU) per serving** | **Percent DV\*** |
| Cod liver oil, 1 tablespoon | 34.0 | 1,360 | 170 |
| Trout (rainbow), farmed, cooked, 3 ounces | 16.2 | 645 | 81 |
| Salmon (sockeye), cooked, 3 ounces | 14.2 | 570 | 71 |
| Mushrooms, white, raw, sliced, exposed to UV light, ½ cup | 9.2 | 366 | 46 |
| Milk, 2% milkfat, vitamin D fortified, 1 cup | 2.9 | 120 | 15 |
| Soy, almond, and oat milks, vitamin D fortified, various brands, 1 cup | 2.5–3.6 | 100–144 | 13–18 |
| Ready-to-eat cereal, fortified with 10% of the DV for vitamin D, 1 serving | 2.0 | 80 | 10 |
| Sardines (Atlantic), canned in oil, drained, 2 sardines | 1.2 | 46 | 6 |
| Egg, 1 large, scrambled\*\* | 1.1 | 44 | 6 |
| Liver, beef, braised, 3 ounces | 1.0 | 42 | 5 |
| Tuna fish (light), canned in water, drained, 3 ounces | 1.0 | 40 | 5 |
| Cheese, cheddar, 1.5 ounce | 0.4 | 17 | 2 |
| Mushrooms, portabella, raw, diced, ½ cup | 0.1 | 4 | 1 |
| Chicken breast, roasted, 3 ounces | 0.1 | 4 | 1 |
| Beef, ground, 90% lean, broiled, 3 ounces | 0 | 1.7 | 0 |
| Broccoli, raw, chopped, ½ cup | 0 | 0 | 0 |
| Carrots, raw, chopped, ½ cup | 0 | 0 | 0 |
| Almonds, dry roasted, 1 ounce | 0 | 0 | 0 |
| Apple, large | 0 | 0 | 0 |
| Banana, large | 0 | 0 | 0 |
| Rice, brown, long-grain, cooked, 1 cup | 0 | 0 | 0 |
| Whole wheat bread, 1 slice | 0 | 0 | 0 |
| Lentils, boiled, ½ cup | 0 | 0 | 0 |
| Sunflower seeds, roasted, ½ cup | 0 | 0 | 0 |
| Edamame, shelled, cooked, ½ cup | 0 | 0 | 0 |

\* DV = Daily Value. The FDA developed DVs to help consumers compare the nutrient contents of foods and dietary supplements within the context of a total diet. The DV for vitamin D is 20 mcg (800 IU) for adults and children age 4 years and older [[26](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en26)]. The labels must list vitamin D content in mcg per serving and have the option of also listing the amount in IUs in parentheses. Foods providing 20% or more of the DV are considered to be high sources of a nutrient, but foods providing lower percentages of the DV also contribute to a healthful diet.  
\*\* Vitamin D is in the yolk.

The U.S. Department of Agriculture’s (USDA’s) [FoodData Central](https://fdc.nal.usda.gov/)[external link disclaimer](https://ods.od.nih.gov/About/exit_disclaimer.aspx) lists the nutrient content of many foods and provides a comprehensive list of foods containing vitamin D arranged by [nutrient content](https://ods.od.nih.gov/pubs/usdandb/VitaminD-Content.pdf) and by [food name](https://ods.od.nih.gov/pubs/usdandb/VitaminD-Food.pdf). However, FoodData Central does not include the amounts of 25(OH)D in foods.

### Sun exposure

Most people in the world meet at least some of their vitamin D needs through exposure to sunlight [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. Type B UV (UVB) radiation with a wavelength of approximately 290–320 nanometers penetrates uncovered skin and converts cutaneous 7-dehydrocholesterol to previtamin D3, which in turn becomes vitamin D3. Season, time of day, length of day, cloud cover, smog, skin melanin content, and sunscreen are among the factors that affect UV radiation exposure and vitamin D synthesis. Older people and people with dark skin are less able to produce vitamin D from sunlight [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. UVB radiation does not penetrate glass, so exposure to sunshine indoors through a window does not produce vitamin D [[27](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en27)].

The factors that affect UV radiation exposure, individual responsiveness, and uncertainties about the amount of sun exposure needed to maintain adequate vitamin D levels make it difficult to provide guidelines on how much sun exposure is required for sufficient vitamin D synthesis [[15](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en15),[28](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en28)]. Some expert bodies and vitamin D researchers suggest, for example, that approximately 5–30 minutes of sun exposure, particularly between 10 a.m. and 4 p.m., either daily or at least twice a week to the face, arms, hands, and legs without sunscreen usually leads to sufficient vitamin D synthesis [[13](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en13),[15](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en15),[28](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en28)]. Moderate use of commercial tanning beds that emit 2% to 6% UVB radiation is also effective [[13](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en13),[29](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en29)].

However, despite the importance of the sun for vitamin D synthesis, limiting skin exposure to sunlight and UV radiation from tanning beds is prudent [[28](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en28)]. UV radiation is a carcinogen, and UV exposure is the most preventable cause of skin cancer. Federal agencies and national organizations advise taking photoprotective measures to reduce the risk of skin cancer, including using sunscreen with a sun protection factor (SPF) of 15 or higher, whenever people are exposed to the sun [[28](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en28),[30](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en30)]. Sunscreens with an SPF of 8 or more appear to block vitamin D-producing UV rays. In practice, however, people usually do not apply sufficient amounts of sunscreen, cover all sun-exposed skin, or reapply sunscreen regularly. Their skin probably synthesizes some vitamin D, even with typically applied sunscreen amounts [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1),[28](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en28)].

### Dietary supplements

Dietary supplements can contain vitamins D2 or D3. Vitamin D2 is manufactured using UV irradiation of ergosterol in yeast, and vitamin D3 is typically produced with irradiation of 7-dehydrocholesterol from lanolin obtained from the wool of sheep [[13](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en13),[31](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en31)]. An animal-free version of vitamin D3 sourced from lichen is also available [[32](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en32)]. People who avoid all animal-sourced products can contact dietary supplement manufacturers to ask about their sourcing and processing techniques.

Both vitamins D2 and D3 raise serum 25(OH)D levels, and they seem to have equivalent ability to cure rickets [[4](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en4)]. In addition, most steps in the metabolism and actions of vitamins D2 and D3 are identical. However, most evidence indicates that vitamin D3 increases serum 25(OH)D levels to a greater extent and maintains these higher levels longer than vitamin D2, even though both forms are well absorbed in the gut [[33-36](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en33)].

Some studies have used dietary supplements containing the 25(OH)D3 form of vitamin D. Per equivalent microgram dose, 25(OH)D3 is three to five times as potent as vitamin D3 [[37](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en37),[38](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en38)]. However, no 25(OH)D3 dietary supplements appear to be available to consumers on the U.S. market at this time [[32](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en32)].

## Vitamin D Intakes and Status

Most people in the United States consume less than recommended amounts of vitamin D. An analysis of data from the 2015–2016 National Health and Nutrition Examination Survey (NHANES) found that average daily vitamin D intakes from foods and beverages were 5.1 mcg (204 IU) in men, 4.2 mcg (168 IU) in women, and 4.9 mcg (196 IU) in children age 2–19 years [[39](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en39)]. In fact, 2013–2016 NHANES data showed that 92% of men, more than 97% of women, and 94% of people age 1 year and older ingested less than the EAR of 10 mcg (400 IU) of vitamin D from food and beverages [[40](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en40)].

The analysis of 2015–2016 data also showed that 28% of all individuals age 2 years and older in the United States took a dietary supplement containing vitamin D [[39](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en39)]. In addition, 26% of participants age 2–5 years and 14% of those age 6–11 years took supplements; rates increased with age from 10% of those age 12–19 years to 49% of men and 59% of women age 60 and older. Total vitamin D intakes were three times higher with supplement use than with diet alone; the mean intake from foods and beverages alone for individuals age 2 and older was 4.8 mcg (192 IU) but increased to 19.9 mcg (796 IU) when dietary supplements were included.

Some people take very high doses of vitamin D supplements. In 2013–2014, an estimated 3.2% of the U.S. adult population took supplements containing 100 mcg (4,000 IU) or more vitamin D [[41](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en41)].

One might expect a large proportion of the U.S. population to have vitamin D inadequacy on the basis of vitamin D intakes from foods, beverages, and even dietary supplements. However, comparing vitamin D intakes to serum 25(OH)D levels is problematic. One reason is that sun exposure affects vitamin D status, so serum 25(OH)D levels are usually higher than would be predicted on the basis of vitamin D dietary intakes alone [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. Another reason is that animal foods contain some 25(OH)D. This form of vitamin D is not included in intake surveys and is considerably more potent than vitamins D2 or D3 at raising serum 25(OH)D levels [[42](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en42)].

An analysis of NHANES 2011–2014 data on serum 25(OH)D levels found that most people in the United States age 1 year and older had sufficient vitamin D intakes according to the FNB thresholds [[43](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en43)]. However, 18% were at risk of inadequacy (levels of 30–49 nmol/L [12–19.6 ng/mL]), and 5% were at risk of deficiency (levels below 30 nmol/L [12 ng/mL]). Four percent had levels higher than 125 nmol/L (50 ng/mL). Proportions at risk of deficiency were lowest among children age 1–5 years (0.5%), peaked at 7.6% in adults age 20–39 years, and fell to 2.9% among adults age 60 years and older; patterns were similar for risks of inadequacy. Rates of deficiency varied by race and ethnicity: 17.5% of non-Hispanic Blacks were at risk of vitamin D deficiency, as were 7.6% of non-Hispanic Asians, 5.9% of Hispanics, and 2.1% of non-Hispanic White people. Again, the pattern was similar for the risk of inadequacy. Vitamin D status in the United States remained stable in the decade between 2003–2004 and 2013–2014.

## Vitamin D Deficiency

People can develop vitamin D deficiency when usual intakes are lower over time than recommended levels, exposure to sunlight is limited, the kidneys cannot convert 25(OH)D to its active form, or absorption of vitamin D from the digestive tract is inadequate. Diets low in vitamin D are more common in people who have milk allergy or lactose intolerance and those who consume an ovo-vegetarian or vegan diet [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)].

In children, vitamin D deficiency is manifested as rickets, a disease characterized by a failure of bone tissue to become properly mineralized, resulting in soft bones and skeletal deformities [[44](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en44)]. In addition to bone deformities and pain, severe rickets can cause failure to thrive, developmental delay, hypocalcemic seizures, tetanic spasms, cardiomyopathy, and dental abnormalities [[45](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en45),[46](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en46)].

Prolonged exclusive breastfeeding without vitamin D supplementation can cause rickets in infants, and, in the United States, rickets is most common among breastfed Black infants and children [[47](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en47)]. In one Minnesota county, the incidence rate of rickets in children younger than 3 years in the decade beginning in 2000 was 24.1 per 100,000 [[48](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en48)]. Rickets occurred mainly in Black children who were breastfed longer, were born with low birthweight, weighed less, and were shorter than other children. The incidence rate of rickets in the infants and children (younger than 7) seen by 2,325 pediatricians throughout Canada was 2.9 per 100,000 in 2002–2004, and almost all patients with rickets had been breastfed [[49](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en49)].

The fortification of milk (a good source of calcium) and other staples, such as breakfast cereals and margarine, with vitamin D beginning in the 1930s along with the use of cod liver oil made rickets rare in the United States [[28](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en28),[50](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en50)]. However, the incidence of rickets is increasing globally, even in the United States and Europe, especially among immigrants from African, Middle-Eastern, and Asian countries [[51](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en51)]. Possible explanations for this increase include genetic differences in vitamin D metabolism, dietary preferences, and behaviors that lead to less sun exposure [[45](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en45),[46](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en46)].

In adults and adolescents, vitamin D deficiency can lead to osteomalacia, in which existing bone is incompletely or defectively mineralized during the remodeling process, resulting in weak bones [[46](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en46)]. Signs and symptoms of osteomalacia are similar to those of rickets and include bone deformities and pain, hypocalcemic seizures, tetanic spasms, and dental abnormalities [[45](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en45)].

Screening for vitamin D status is becoming a more common part of the routine laboratory bloodwork ordered by primary-care physicians, irrespective of any indications for this practice [[6](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en6),[52-54](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en52)]. No studies have examined whether such screening for vitamin D deficiency results in improved health outcomes [[55](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en55)]. The U.S. Preventive Services Task Force (USPSTF) found insufficient evidence to assess the benefits and harms of screening for vitamin D deficiency in asymptomatic adults [[6](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en6)]. It added that no national professional organization recommends population screening for vitamin D deficiency.

## Groups at Risk of Vitamin D Inadequacy

Obtaining sufficient vitamin D from natural (nonfortified) food sources alone is difficult. For many people, consuming vitamin D-fortified foods and exposing themselves to some sunlight are essential for maintaining a healthy vitamin D status. However, some groups might need dietary supplements to meet their vitamin D requirements. The following groups are among those most likely to have inadequate vitamin D status.

### Breastfed infants

Consumption of human milk alone does not ordinarily enable infants to meet vitamin D requirements, because it provides less than 0.6 to 2.0 mcg/L (25 to 78 IU/L) [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1),[56](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en56),[57](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en57)]. The vitamin D content of human milk is related to the mother’s vitamin D status; studies suggest that the breastmilk of mothers who take daily supplements containing at least 50 mcg (2,000 IU) vitamin D3 have higher levels of the nutrient [[57](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en57),[58](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en58)].

Although UVB exposure can produce vitamin D in infants, the American Academy of Pediatrics (AAP) advises parents to keep infants younger than 6 months out of direct sunlight, dress them in protective clothing and hats, and apply sunscreen on small areas of exposed skin when sun exposure is unavoidable [[59](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en59)]. The AAP recommends 10 mcg (400 IU)/day vitamin D supplements for exclusively and partially breastfed infants starting shortly after birth and lasting until they are weaned and consume at least 1,000 mL/day vitamin D-fortified formula or whole milk [[57](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en57)]. The AAP also recommends 10 mcg (400 IU)/day supplemental vitamin D for all infants who are not breastfed and ingest less than 1,000 mL/day vitamin D-fortified formula or milk. An analysis of NHANES 2009–2016 data found that only 20.5% of breastfed infants and 31.1% of infants who were not breastfed ingested these recommended amounts of supplements [[60](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en60)].

### Older adults

Older adults are at increased risk of developing vitamin D insufficiency, partly because the skin’s ability to synthesize vitamin D declines with age [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1),[61](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en61)]. In addition, older adults are likely to spend more time than younger people indoors, and they might have inadequate dietary intakes of the vitamin [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)].

### People with limited sun exposure

Homebound individuals; people who wear long robes, dresses, or head coverings for religious reasons; and people with occupations that limit sun exposure are among the groups that are unlikely to obtain adequate amounts of vitamin D from sunlight [[62](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en62)]. The use of sunscreen also limits vitamin D synthesis from sunlight. However, because the extent and frequency of sunscreen use are unknown, the role that sunscreen may play in reducing vitamin D synthesis is unclear [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)].

### People with dark skin

Greater amounts of the pigment melanin in the epidermal layer of the skin result in darker skin and reduce the skin’s ability to produce vitamin D from sunlight [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. Black Americans, for example, typically have lower serum 25(OH)D levels than White Americans. However, whether these lower levels in persons with dark skin have significant health consequences is not clear [[14](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en14)]. Those of African American ancestry, for example, have lower rates of bone fracture and osteoporosis than do Whites (see the section below on bone health and osteoporosis).

### People with conditions that limit fat absorption

Because vitamin D is fat soluble, its absorption depends on the gut’s ability to absorb dietary fat [[4](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en4)]. Fat malabsorption is associated with medical conditions that include some forms of liver disease, cystic fibrosis, celiac disease, Crohn’s disease, and ulcerative colitis [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1),[63](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en63)]. In addition to having an increased risk of vitamin D deficiency, people with these conditions might not eat certain foods, such as dairy products (many of which are fortified with vitamin D), or eat only small amounts of these foods. Individuals who have difficulty absorbing dietary fat might therefore require vitamin D supplementation [[63](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en63)].

### People with obesity or who have undergone gastric bypass surgery

Individuals with a body mass index (BMI) of 30 or more have lower serum 25(OH)D levels than individuals without obesity. Obesity does not affect the skin’s capacity to synthesize vitamin D. However, greater amounts of subcutaneous fat sequester more of the vitamin [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. People with obesity might need greater intakes of vitamin D to achieve 25(OH)D levels similar to those of people with normal weight [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1),[64](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en64),[65](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en65)].

Individuals with obesity who have undergone gastric bypass surgery can also become vitamin D deficient. In this procedure, part of the upper small intestine, where vitamin D is absorbed, is bypassed, and vitamin D that is mobilized into the bloodstream from fat stores might not raise 25(OH)D to adequate levels over time [[66](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en66),[67](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en67)]. Various expert groups—including the American Association of Metabolic and Bariatric Surgery, The Obesity Society, and the British Obesity and Metabolic Surgery Society—have developed guidelines on vitamin D screening, monitoring, and replacement before and after bariatric surgery [[66](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en66),[68](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en68)]

## Vitamin D and Health

The FNB committee that established DRIs for vitamin D found that the evidence was inadequate or too contradictory to conclude that the vitamin had any effect on a long list of potential health outcomes (e.g., on resistance to chronic diseases or functional measures), except for measures related to bone health. Similarly, in a review of data from nearly 250 studies published between 2009 and 2013, the Agency for Healthcare Research and Quality concluded that no relationship could be firmly established between vitamin D and health outcomes other than bone health [[69](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en69)]. However, because research has been conducted on vitamin D and numerous health outcomes, this section focuses on seven diseases, conditions, and interventions in which vitamin D might be involved: bone health and osteoporosis, cancer, cardiovascular disease (CVD), depression, multiple sclerosis (MS), type 2 diabetes, and weight loss.

Most of the studies described in this section measured serum 25(OH)D levels using various methods that were not standardized by comparing them to the best methods. Use of unstandardized 25(OH)D measures can raise questions about the accuracy of the results and about the validity of conclusions drawn from studies that use such measures and, especially, from meta-analyses that pool data from many studies that use different unstandardized measures [[5](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en5),[9](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en9),[70](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en70)]. More information about assay standardization is available from the [Vitamin D Standardization Program](https://ods.od.nih.gov/Research/VitaminD.aspx#vdsp) webpage.

### Bone health and osteoporosis

Bone is constantly being remodeled. However, as people age—and particularly in women during menopause—bone breakdown rates overtake rates of bone building. Over time, bone density can decline, and osteoporosis can eventually develop [[71](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en71)].

More than 53 million adults in the United States have or are at risk of developing osteoporosis, which is characterized by low bone mass and structural deterioration of bone tissue that increases bone fragility and the risk of bone fractures [[72](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en72)]. About 2.3 million osteoporotic fractures occurred in the United States in 2015 [[73](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en73)]. Osteoporosis is, in part, a long-term effect of calcium and/or vitamin D insufficiency, in contrast to rickets and osteomalacia, which result from vitamin D deficiency. Osteoporosis is most often associated with inadequate calcium intakes, but insufficient vitamin D intakes contribute to osteoporosis by reducing calcium absorption [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)].

Bone health also depends on support from the surrounding muscles to assist with balance and postural sway and thereby reduce the risk of falling. Vitamin D is also needed for the normal development and growth of muscle fibers. In addition, inadequate vitamin D levels can adversely affect muscle strength and lead to muscle weakness and pain (myopathy) [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)].

Most trials of the effects of vitamin D supplements on bone health also included calcium supplements, so isolating the effects of each nutrient is difficult. In addition, studies provided different amounts of nutrients and used different dosing schedules.

#### Clinical trial evidence on older adults

Among postmenopausal women and older men, many clinical trials have shown that supplements of both vitamin D and calcium result in small increases in bone mineral density throughout the skeleton [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1),[74](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en74)]. They also help reduce fracture rates in institutionalized older people. However, the evidence on the impact of vitamin D and calcium supplements on fractures in community-dwelling individuals is inconsistent.

The USPSTF evaluated 11 randomized clinical trials of vitamin D and/or calcium supplementation in a total of 51,419 healthy, community-dwelling adults age 50 years and older who did not have osteoporosis, vitamin D deficiency, or prior fractures [[75](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en75),[76](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en76)]. It concluded that the current evidence was insufficient to evaluate the benefits and harms of supplementation to prevent fractures. In addition, the USPSTF recommended against supplementation with 10 mcg (400 IU) or less of vitamin D and 1,000 mg or less of calcium to prevent fractures in this population, but it could not determine the balance of benefits and harms from higher doses.

The USPSTF also reviewed the seven published studies on the effects of vitamin D supplementation (two of them also included calcium supplementation) on the risk of falls in community-dwelling adults age 65 years or older who did not have osteoporosis or vitamin D deficiency. It concluded with moderate certainty that vitamin D supplementation does not reduce the numbers of falls or injuries, such as fractures, resulting from falls [[77](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en77),[78](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en78)]. Another recent systematic review also found that vitamin D and calcium supplements had no beneficial effects on fractures, falls, or bone mineral density [[79](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en79),[80](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en80)]. In contrast, a meta-analysis of six trials in 49,282 older adults found that daily vitamin D (10 or 20 mcg [400 IU or 800 IU]/day) and calcium (800 or 1,200 mg/day) supplementation for a mean of 5.9 years reduced the risk of any fracture by 6% and of hip fracture by 16% [[81](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en81)].

One systematic review and meta-analysis of 11 randomized, controlled trials published through 2018 of vitamin D supplementation alone (10–20 mcg [400–800 IU]/day or more at least every week or as rarely as once a year) for 9 months to 5 years found that the supplements provided no protection from fractures in 34,243 older adults [[81](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en81)].

More recently, a 2022 ancillary study of the Vitamin D and Omega-3 Trial (VITAL; described in the Cancer section below) investigated whether supplemental vitamin D3 (50 mcg [2,000 IU]/day) would lower the risk of fractures in 25,871 generally healthy men age 50 years and older and women age 55 years and older over a median follow-up of 5.3 years [[82](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en82)]. The mean age of all participants was 67.1 years; 50.6% were women and 20.2% were Black. Most participants were vitamin D sufficient; at baseline, only 2.4% had serum 25(OH)D levels less than 30 nmol/L (12 ng/mL), and 12.9% less than 50 nmol/L (20 ng/mL). Vitamin D supplementation did not lower the risk of total fractures, hip fractures, or nonvertebral fractures as compared with placebo. No substantial between-group differences in fracture incidence were found by race, ethnic group, BMI, age, baseline 25(OH)D levels, or whether participants took supplemental calcium, were at high fracture risk, or had a history of fragility fractures.

#### Vitamin D supplements for bone health in minority populations

Bone mineral density, bone mass, and fracture risk are correlated with serum 25(OH)D levels in White Americans and Mexican Americans, but not in Black Americans [[14](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en14),[83](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en83)]. Factors such as adiposity, skin pigmentation, vitamin D binding protein polymorphisms, and genetics contribute to differences in 25(OH)D levels between Black and White Americans.

One clinical trial randomized 260 Black women age 60 years and older (mean age 68.2 years) to receive 60 to 120 mcg (2,400 to 4,800 IU) per day vitamin D3 supplementation to maintain serum 25(OH)D levels above 75 nmol/L (30 ng/mL) for 3 years [[84](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en84)]. The results showed no association between 25(OH)D levels or vitamin D dose and the risk of falling in the 184 participants who completed the study. In fact, Black Americans might have a greater risk than White Americans of falls and fractures with daily vitamin D intakes of 50 mcg (2,000 IU) or more [[14](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en14)]. Furthermore, the bone health of older Black American women does not appear to benefit from raising serum 25(OH)D levels beyond 50 nmol/L (20 ng/mL) [[84](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en84)].

#### Vitamin D supplements and muscle function

Studies examining the effects of supplemental vitamin D on muscle strength and on rate of decline in muscle function have had inconsistent results [[55](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en55)]. One recent clinical trial, for example, randomized 78 frail and near-frail adults age 65 years and older to receive 20 mcg (800 IU) vitamin D3, 10 mcg 25(OH)D, or placebo daily for 6 months. The groups showed no significant differences in measures of muscle strength or performance [[85](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en85)]. Another study randomized 100 community-dwelling men and women age 60 years and older (most were White) with serum 25(OH)D levels of 50 nmol/L (20 ng/ml) or less to 800 IU vitamin D3 or placebo for 1 year [[86](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en86)]. Participants in the treatment group whose serum 25(OH)D level was less than 70 nmol/L (28 ng/ml) after 4 months received an additional 800 IU/day vitamin D3. Despite increasing serum 25(OH)D levels to an average of more than 80 nmol/L (32 ng/ml), vitamin D supplementation did not affect lower-extremity power, strength, or lean mass.

#### Conclusions about vitamin D supplements and bone health

All adults should consume recommended amounts of vitamin D and calcium from foods and supplements if needed. Older women and men should consult their health care providers about their needs for both nutrients as part of an overall plan to maintain bone health and to prevent or treat osteoporosis.

### Cancer

Laboratory and animal studies suggest that vitamin D might inhibit carcinogenesis and slow tumor progression by, for example, promoting cell differentiation and inhibiting metastasis. Vitamin D might also have anti-inflammatory, immunomodulatory, proapoptotic, and antiangiogenic effects [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1),[87](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en87)]. Observational studies and clinical trials provide mixed evidence on whether vitamin D intakes or serum levels affect cancer incidence, progression, or mortality risk.

#### Total cancer incidence and mortality

Some observational studies show associations between low serum levels of 25(OH)D and increased risks of cancer incidence and death. In a meta-analysis of 16 prospective cohort studies in a total of 137,567 participants who had 8,345 diagnoses of cancer, 5,755 participants died from cancer [[88](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en88)]. A 50 nmol/L (20 ng/mL) increase in 25(OH)D levels was associated with an 11% reduction in total cancer incidence rates and, in women but not men, a 24% reduction in cancer mortality rates. A meta-analysis of prospective studies that evaluated the association between serum 25(OH)D levels and cancer incidence (8 studies) or cancer mortality (16 studies) found that cancer risk decreased by 7% and cancer mortality rates decreased by 2% with each 20 nmol/L (8 ng/mL) increase in serum 25(OH)D levels [[89](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en89)]. Importantly, not all observational studies found higher vitamin D status to be beneficial, and the studies varied considerably in study populations, baseline comorbidities, and measurement of vitamin D levels.

Clinical trial evidence provides some support for the observational findings. For example, three meta-analyses of clinical trial evidence found that vitamin D supplementation does not affect cancer incidence but does significantly reduce total cancer mortality rates by 12%–13% [[90-92](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en90)]. In the most recent meta-analysis, 10 randomized clinical trials (including the VITAL trial described below) that included 6,537 cancer cases provided 10 to 50 mcg (400 to 2,000 IU) vitamin D3 daily (six trials) or 500 mcg (20,000 IU)/week to 12,500 mcg (500,000 IU)/year boluses of vitamin D3 (four trials) [[91](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en91)]. The study reports included 3–10 years of follow-up data. The vitamin D supplements were associated with serum 25(OH)D levels of 54 to 135 nmol/L (21.6 to 54 ng/mL). Vitamin D supplementation reduced cancer mortality rates by 13%, and most of the benefit occurred with daily supplementation.

The largest clinical trial, VITAL, to investigate the effects of vitamin D supplementation on the primary prevention of cancer in the general population gave 50 mcg (2,000 IU)/day vitamin D3 supplements with or without 1,000 mg/day marine omega-3 fatty acids or a placebo for a median of 5.3 years [[93](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en93)]. The study included 25,871 men age 50 years and older and women age 55 years and older who had no history of cancer, and most had adequate serum 25(OH)D levels at baseline. Rates of breast, prostate, and colorectal cancer did not differ significantly between the vitamin D and placebo groups. However, normal-weight participants had greater reductions in cancer incidence and mortality rates than those with overweight or obesity.

A few studies have examined the effect of vitamin D supplementation on specific cancers. Below are brief descriptions of studies of vitamin D and its association with, or effect on, breast, colorectal, lung, pancreatic, and prostate cancers.

#### Breast cancer

Some observational studies support an inverse association between 25(OH)D levels and breast cancer risk and mortality, but others do not [[94-97](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en94)]. The Women’s Health Initiative clinical trial randomized 36,282 postmenopausal women to receive 400 IU vitamin D3 plus 1,000 mg calcium daily or a placebo for a mean of 7 years [[98](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en98)]. The vitamin D3 and calcium supplements did not reduce breast cancer incidence, and 25(OH)D levels at the start of the study were not associated with breast cancer risk [[99](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en99)].

In a subsequent investigation for 4.9 years after the study’s end, women who had taken the vitamin D and calcium supplements (many of whom continued to take them) had an 18% lower risk of in situ (noninvasive) breast cancer [[100](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en100)]. However, women with vitamin D intakes higher than 15 mcg (600 IU)/day at the start of the trial and who received the supplements experienced a 28% increased risk of invasive (but not in situ) breast cancer.

#### Colorectal cancer

A large case-control study included 5,706 individuals who developed colorectal cancer and whose 25(OH)D levels were assessed a median of 5.5 years from blood draw to cancer diagnosis and 7,105 matched controls [[101](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en101)]. The results showed an association between 25(OH)D levels lower than 30 nmol/L (12 ng/mL) and a 31% higher colorectal cancer risk. Levels of 75 to less than 87.5 nmol/L (30 to less than 35 ng/mL) and 87.5 to less than 100 nmol/L (35 to less than 40 ng/mL) were associated with a 19% and 27% lower risk, respectively. The association was substantially stronger in women.

In the Women’s Health Initiative clinical trial (described above), vitamin D3 and calcium supplements had no effect on rates of colorectal cancer. In a subsequent investigation for 4.9 years after the study’s end, women who had taken the vitamin D and calcium supplements (many of whom continued to take them) still had the same colorectal cancer risk as those who received placebo [[100](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en100)].

Another study included 2,259 healthy individuals age 45 to 75 years who had had one or more serrated polyps (precursor lesions to colorectal cancer) that had been removed [[102](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en102)]. These participants were randomized to take 25 mcg (1,000 IU) vitamin D3, 1,200 mg calcium, both supplements, or a placebo daily for 3–5 years, followed by an additional 3–5 years of observation after participants stopped the treatment. Vitamin D alone did not significantly affect the development of new serrated polyps, but the combination of vitamin D with calcium increased the risk almost fourfold. The VITAL trial found no association between vitamin D supplementation and the risk of colorectal adenomas or serrated polyps [[103](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en103)].

#### Lung cancer

A study of cohorts that included 5,313 participants who developed lung cancer and 5,313 matched controls found no association between serum 25(OH)D levels and risk of subsequent lung cancer, even when the investigators analyzed the data by sex, age, race and ethnicity, and smoking status [[104](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en104)].

#### Pancreatic cancer

One study comparing 738 men who developed pancreatic cancer to 738 matched controls found no relationship between serum 25(OH)D levels and risk of pancreatic cancer [[105](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en105)]. Another study that compared 200 male smokers in Finland with pancreatic cancer to 400 matched controls found that participants in the highest quintile of 25(OH)D levels (more than 65.5 nmol/L [26.2 ng/mL]) had a threefold greater risk of developing pancreatic cancer over 16.7 years than those in the lowest quintile (less than 32 nmol/L [12.8 ng/mL]) [[106](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en106)]. An investigation that pooled data from 10 studies of cancer in 12,205 men and women found that concentrations of 25(OH)D greater than 75 nmol/L (30 ng/mL) but less than 100 nmol/L (40 ng/mL) did not reduce the risk of pancreatic cancer. However, the results did show an increased risk of pancreatic cancer with 25(OH)D levels of 100 nmol/L (40 ng/mL) or above [[107](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en107)].

#### Prostate cancer

Research to date provides mixed evidence on whether levels of 25(OH)D are associated with the development of prostate cancer. Several studies published in 2014 suggested that high levels of 25(OH)D might increase the risk of prostate cancer. For example, a meta-analysis of 21 studies that included 11,941 men with prostate cancer and 13,870 controls found a 17% higher risk of prostate cancer for participants with higher levels of 25(OH)D [[108](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en108)]. What constituted a higher level varied by study but was typically at least 75 nmol/L (30 ng/mL). In a cohort of 4,733 men, of which 1,731 had prostate cancer, those with 25(OH)D levels of 45–70 nmol/L (18–28 ng/mL) had a significantly lower risk of the disease than men with either lower or higher values [[109](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en109)]. This U-shaped association was most pronounced for men with the most aggressive forms of prostate cancer. A case-control analysis of 1,695 cases of prostate cancer and 1,682 controls found no associations between 25(OH)D levels and prostate cancer risk [[110](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en110)]. However, higher serum 25(OH)D levels (at a cut point of 75 nmol/L [30 ng/mL]) were linked to a modestly higher risk of slow-growth prostate cancer and a more substantial lower risk of aggressive disease.

Since 2014, however, several published studies and meta-analyses have found no relationship between 25(OH)D levels and prostate cancer risk [[111](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en111),[112](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en112)]. For example, an analysis was conducted of 19 prospective studies that provided data on prediagnostic levels of 25(OH)D for 13,462 men who developed prostate cancer and 20,261 control participants [[113](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en113)]. Vitamin D deficiency or insufficiency did not increase the risk of prostate cancer, and higher 25(OH)D concentrations were not associated with a lower risk.

Several studies have examined whether levels of 25(OH)D in men with prostate cancer are associated with a lower risk of death from the disease or from any cause. One study included 1,119 men treated for prostate cancer whose plasma 25(OH)D levels were measured 4.9 to 8.6 years after their diagnosis. Among the 198 participants who died (41 deaths were due to prostate cancer), 25(OH)D levels were not associated with risk of death from prostate cancer or any cause [[114](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en114)]. However, a meta-analysis of seven cohort studies that included 7,808 men with prostate cancer found higher 25(OH)D levels to be significantly associated with lower mortality rates from prostate cancer or any other cause [[115](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en115)]. A dose-response analysis found that each 20 nmol/L [8 ng/mL] increase in 25(OH)D was associated with a 9% lower risk of both all-cause and prostate cancer-specific mortality.

For men with prostate cancer, whether vitamin D supplementation lengthens cancer-related survival is not clear. A meta-analysis of three randomized controlled trials in 1,273 men with prostate cancer found no significant differences in total mortality rates between those receiving vitamin D supplementation (from 10 mcg [400 IU]/day for 28 days to 45 mcg [1,800 IU] given in three doses total at 2-week intervals) and those receiving a placebo [[116](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en116)].

#### Conclusions about vitamin D and cancer

The USPSTF stated that, due to insufficient evidence, it was unable to assess the balance of benefits and harms of supplemental vitamin D to prevent cancer [[117](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en117)]. Taken together, studies to date do not indicate that vitamin D with or without calcium supplementation reduces the incidence of cancer, but adequate or higher 25(OH)D levels might reduce cancer mortality rates. Further research is needed to determine whether vitamin D inadequacy increases cancer risk, whether greater exposure to the nutrient can prevent cancer, and whether some individuals could have an increased risk of cancer because of their vitamin D status over time.

### Cardiovascular disease

Vitamin D helps regulate the renin-angiotensin-aldosterone system (and thereby blood pressure), vascular cell growth, and inflammatory and fibrotic pathways [[118](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en118)]. Vitamin D deficiency is associated with vascular dysfunction, arterial stiffening, left ventricular hypertrophy, and hyperlipidemia [[119](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en119)]. For these reasons, vitamin D has been linked to heart health and risk of CVD.

Observational studies support an association between higher serum 25(OH)D levels and a lower risk of CVD incidence and mortality. For example, a meta-analysis included 34 observational studies that followed 180,667 participants (mean age greater than 50 years) for 1.3 to more than 32 years. The results showed that baseline serum 25(OH)D levels were inversely associated with total number of CVD events (including myocardial infarction, ischemic heart disease, heart failure, and stroke) and mortality risk [[120](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en120)]. Overall, the risk of CVD events was 10% lower for each 25 nmol/L (10 ng/mL) increase in serum 25(OH)D.

Another large observational study that followed 247,574 adults from Denmark for 0–7 years found that levels of 25(OH)D that were low (about 12.5 nmol/L [5 ng/mL]) and high (about 125 nmol/L [50 ng/mL]) were associated with a greater risk of mortality from CVD, stroke, and acute myocardial infarction [[121](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en121)]. Other meta-analyses of prospective studies have found associations between lower vitamin D status measured by serum 25(OH)D levels or vitamin D intakes and an increased risk of ischemic stroke, ischemic heart disease, myocardial infarction, and early death [[122](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en122),[123](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en123)].

In contrast to the observational studies, clinical trials have provided little support for the hypothesis that supplemental vitamin D reduces the risk of CVD or CVD mortality. For example, a 3-year trial in New Zealand randomized 5,110 adults (mean age 65.9 years) to a single dose of 5,000 mcg (200,000 IU) vitamin D3 followed by 2,500 mcg (100,000 IU) each month or a placebo for a median of 3.3 years [[124](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en124)]. Vitamin D supplementation had no effect on the incidence rate of myocardial infarction, angina, heart failure, arrhythmia, arteriosclerosis, stroke, venous thrombosis, or death from CVD. Similarly, the VITAL clinical trial described above found that vitamin D supplements did not significantly decrease rates of heart attacks, strokes, coronary revascularization, or deaths from cardiovascular causes [[93](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en93)]. Moreover, the effects did not vary by baseline serum 25(OH)D levels or whether participants took the trial’s omega-3 supplement in addition to vitamin D.

However, another clinical trial designed to investigate bone fracture risk found that 800 IU/day vitamin D3 (with or without calcium) or a placebo in 5,292 adults age 70 years and older for a median of 6.2 years offered protection from cardiac failure, but not myocardial infarction or stroke [[125](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en125)].

High serum cholesterol levels and hypertension are two of the main risk factors for CVD. The data on supplemental vitamin D and cholesterol levels are mixed, as shown in one meta-analysis of 41 clinical trials in a total of 3,434 participants (mean age 55 years). The results of this analysis showed that 0.5 mcg (20 IU) to 214 mcg (8,570 IU)/day vitamin D supplementation (mean of 2,795 IU) for 6 weeks to 3 years reduced serum total cholesterol, low-density lipoprotein cholesterol, and triglyceride levels, but not high-density lipoprotein cholesterol levels [[126](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en126)].

Studies of the effects of vitamin D supplements on hypertension have also had mixed findings. In one meta-analysis of 46 clinical trials that included 4,541 participants, vitamin D supplements (typically 40 mcg [1,600 IU]/day or less) for a minimum of 4 weeks had no significant effects on systolic or diastolic blood pressure [[127](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en127)]. In contrast, another meta-analysis of 30 clinical trials in 4,744 participants (mean age 54.5 years) that administered 5 mcg (200 IU) to 300 mcg (12,000 IU)/day vitamin D3 for a mean of 5.6 months showed that more than 20 mcg (800 IU)/day significantly reduced systolic and diastolic blood pressure in normal-weight participants who had hypertension [[128](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en128)]. However, more than 20 mcg (800 IU)/day vitamin D3, when taken with calcium supplements, significantly increased blood pressure in participants with overweight and obesity. Another meta-analysis of genetic studies in 146,581 participants (primarily adults) found that a low vitamin D status increased blood pressure and hypertension risk in people with genetic variants associated with low endogenous production of 25(OH)D [[129](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en129)].

Overall, clinical trials show that vitamin D supplementation does not reduce CVD risk, even for people with low 25(OH)D status (below 20 nmol/L [12 ng/mL]) at baseline [[93](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en93),[124](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en124)].

### Depression

Vitamin D is involved in various brain processes, and vitamin D receptors are present on neurons and glia in areas of the brain thought to be involved in the pathophysiology of depression [[130](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en130)].

A systematic review and meta-analysis of 14 observational studies that included a total of 31,424 adults (mean age ranging from 27.5 to 77 years) found an association between deficient or low levels of 25(OH)D and depression [[130](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en130)].

Clinical trials, however, do not support these findings. For example, a meta-analysis of nine trials with a total of 4,923 adult participants diagnosed with depression or depressive symptoms found no significant reduction in symptoms after supplementation with vitamin D [[131](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en131)]. The trials administered different amounts of vitamin D (ranging from 10 mcg [400 IU]/day to 1,000 mcg [40,000 IU]/week). They also had different study durations (5 days to 5 years), mean participant ages (range, 22 years to 75 years), and baseline 25(OH)D levels; furthermore, some but not all studies administered concurrent antidepressant medications.

Three trials conducted since that meta-analysis also found no effect of vitamin D supplementation on depressive symptoms. One trial included 206 adults (mean age 52 years) who were randomized to take a bolus dose of 2,500 mcg (100,000 IU) vitamin D3 followed by 500 mcg (20,000 IU)/week or a placebo for 4 months [[132](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en132)]. Most participants had minimal or mild depression, had a low mean baseline 25(OH) level of 33.8 nmol/L (13.5 ng/mL), and were not taking antidepressants. The second trial included 155 adults age 60–80 years who had clinically relevant depressive symptoms, no major depressive disorder, and serum 25(OH)D levels less than 50 to 70 nmol/L (20 to 28 ng/mL) depending on the season; in addition, they were not taking antidepressants [[133](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en133),[134](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en134)]. Participants were randomized to take either 30 mcg (1,200 IU)/day vitamin D3 or a placebo for 1 year. In the VITAL trial described above, 16,657 men and women 50 years of age and older with no history of depression and 1,696 with an increased risk of recurrent depression (that had not been medically treated for the past 2 years) were randomized to take 50 mcg (2,000 IU)/day vitamin D3 (with or without fish oil) or a placebo for a median of 5.3 years [[135](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en135)]. The groups showed no significant differences in the incidence and recurrent rates of depression, clinically relevant depressive symptoms, or changes in mood scores.

Overall, clinical trials did not find that vitamin D supplements helped prevent or treat depressive symptoms or mild depression, especially in middle-age to older adults who were not taking prescription antidepressants. No studies have evaluated whether vitamin D supplements may benefit individuals under medical care for clinical depression who have low or deficient 25(OH)D levels and are taking antidepressant medication.

### Multiple sclerosis

MS is an autoimmune disease of the central nervous system that damages the myelin sheath surrounding and protecting nerve cells in the brain and spinal cord. This damage hinders or blocks messages between the brain and body, leading to clinical features, such as vision loss, motor weakness, spasticity, ataxia, tremor, sensory loss, and cognitive impairment [[136](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en136),[137](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en137)]. Some people with MS eventually lose the ability to write, speak, or walk.

The geographical distribution of MS around the world is unequal. Few people near the equator develop the disease, whereas the prevalence is higher further north and south. This uneven distribution has led to speculation that lower vitamin D levels in people who have less sunlight exposure might predispose them to the disease [[137](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en137)].

Many epidemiological and genetic studies have shown an association between MS and low 25(OH)D levels before and after the disease begins [[137](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en137)]. Observational studies suggest that adequate vitamin D levels might reduce the risk of contracting MS and, once MS is present, decrease the risk of relapse and slow the disease’s progression [[138](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en138)]. One study, for example, tested 25(OH)D levels in 1,092 women in Finland an average of 9 years before their MS diagnosis and compared their outcomes with those of 2,123 similar women who did not develop MS [[139](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en139)]. More than half the women who developed MS had deficient or insufficient vitamin D levels. Women with 25(OH)D levels of less than 30 nmol/L (12 ng/mL) had a 43% higher MS risk than women with levels of 50 nmol/L (20 ng/mL) or higher. Among the women with two or more serum 25(OH)D samples taken before diagnosis (which reduced random measurement variation), a 50 nmol/L increase in 25(OH)D was associated with a 41% reduced risk of MS, and 25(OH)D levels less than 30 nmol/L were associated with an MS risk that was twice as high as levels of 50 nmol/L or higher.

Two earlier prospective studies of similar design—one in the United States with 444 non-Hispanic White individuals [[140](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en140)] and the other with 576 individuals in northern Sweden [[141](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en141)]—found that levels of 25(OH)D greater than 99.1 nmol/L (39.6 ng/mL) and at least 75 nmol/L (30 ng/mL), respectively, were associated with a 61%–62% lower risk of MS.

No clinical trials have examined whether vitamin D supplementation can prevent the onset of MS, but several have investigated whether supplemental vitamin D can help manage the disease. A 2018 Cochrane Review analyzed 12 such trials that had a total of 933 participants with MS; the reviewers judged all of these trials to be of low quality [[137](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en137)]. Overall, vitamin D supplementation, when compared with placebo administration, had no effect on relevant clinical outcomes, such as recurrent relapse or worsened disability.

Experts have reached no firm consensus on whether vitamin D can help prevent MS given the lack of clinical trial evidence [[142](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en142)]. In addition, studies have not consistently shown that vitamin D supplementation tempers the signs and symptoms of active MS or reduces rates of relapse.

### Type 2 diabetes

Vitamin D plays a role in glucose metabolism. It stimulates insulin secretion via the vitamin D receptor on pancreatic beta cells and reduces peripheral insulin resistance through vitamin D receptors in the muscles and liver [[143](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en143)]. Vitamin D might be involved in the pathophysiology of type 2 diabetes through its effects on glucose metabolism and insulin signaling as well as its ability to reduce inflammation and improve pancreatic beta-cell function [[1443](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1443),[145](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en145)].

Observational studies have linked lower serum 25(OH)D levels to an increased risk of diabetes, but their results might have been confounded by the fact that many participants were overweight or had obesity and were therefore more predisposed to developing diabetes and having lower 25(OH)D levels [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. A review of 71 observational studies in adults with and without type 2 diabetes from 16 countries found a significant inverse relationship between vitamin D status and blood sugar levels in participants who did and did not have diabetes [[146](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en146)].

In contrast to observational studies, clinical trials provide little support for the benefits of vitamin D supplementation for glucose homeostasis. One trial included 65 adult men and women (mean age 32 years) with overweight or obesity who were otherwise healthy, did not have diabetes, and had low serum vitamin D levels (at or below 50 nmol/L [20 ng/mL]) [[147](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en147)]. The investigators randomly assigned participants to receive either a bolus oral dose of 2,500 mcg (100,000 IU) vitamin D3 followed by 100 mcg (4,000 IU)/day or a placebo for 16 weeks. In the 54 participants who completed the study, vitamin D supplementation did not improve insulin sensitivity or insulin secretion in comparison with placebo.

One systematic review and meta-analysis evaluated 35 clinical trials that included 43,407 adults with normal glucose tolerance, prediabetes, or type 2 diabetes who received a median of 83 mcg (3,332 IU)/day vitamin D supplements or placebo for a median of 16 weeks [[148](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en148)]. Vitamin D had no significant effects on glucose homeostasis, insulin secretion or resistance, or hemoglobin A1c levels (a measure of average blood sugar levels over the previous 2–3 months), irrespective of the study population, vitamin D dose, or trial quality.

Several trials have investigated whether vitamin D supplementation can prevent the transition from prediabetes to diabetes in patients with adequate 25(OH)D levels, and all have had negative results. In a trial in Norway, 511 men and women age 25–80 years (mean age 62 years) with prediabetes received 500 mcg (20,000 IU) vitamin D3 or a placebo each week for 5 years [[149](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en149)]. The results showed no significant differences in rates of progression to type 2 diabetes; in serum glucose, insulin, or hemoglobin A1c levels; or in measures of insulin resistance. At baseline, participants had an adequate mean serum 25(OH)D level of 60 nmol/L (24 ng/mL).

The largest trial to date of vitamin D supplements for diabetes prevention randomized 2,423 men and women age 25 years and older (mean age 60 years) with prediabetes and overweight or obesity (mean BMI of 32.1) to 100 mcg (4,000 IU)/day vitamin D3 or placebo for a median of 2.5 years [[145](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en145)]. Most participants (78%) had adequate serum levels of vitamin D at baseline (at least 50 nmol/L [20 ng/mL]). Vitamin D did not significantly prevent the development of diabetes in comparison with placebo. However, a post hoc analysis showed a 62% lower incidence of diabetes among participants with low baseline serum 25(OH)D levels (less than 30 nmol/L [12 ng/mL]) who took the vitamin D supplement than among those who took the placebo [[145](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en145),[150](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en150)].

Studies have also assessed the value of vitamin D supplementation for managing diabetes, and they have found that the vitamin offers limited benefits. One meta-analysis of 20 clinical trials compared the effects of 0.5 mcg (20 IU)/day to 1,250 mcg (50,000 IU)/week vitamin D supplementation for 2–6 months with those of placebo on glycemic control in 2,703 adults from around the world who had diabetes [[143](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en143)]. The vitamin D reduced insulin resistance to a small but significant degree, especially in people taking more than 50 mcg (2,000 IU)/day who were vitamin D deficient at baseline, had good glycemic control, did not have obesity, and were of Middle Eastern ethnicity. However, the supplementation had no significant effects on fasting blood glucose, hemoglobin A1c, or fasting insulin levels.

Clinical trials to date provide little evidence that vitamin D supplementation helps maintain glucose homeostasis, reduces the risk of progression from prediabetes to type 2 diabetes, or helps manage the disease, particularly in vitamin D-replete individuals.

### Weight loss

Observational studies indicate that greater body weights are associated with lower vitamin D status, and individuals with obesity frequently have marginal or deficient circulating 25(OH)D levels [[151](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en151)]. However, clinical trials do not support a cause-and-effect relationship between vitamin D and weight loss.

A systematic review and meta-analysis of 15 weight-loss intervention studies that used caloric restriction, exercise, or both, but not necessarily vitamin D supplementation or other treatments, found that people who lost weight had significantly greater increases in serum 25(OH)D levels than those who maintained their weight [[152](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en152)]. In another study, 10 mcg (400 IU)/day vitamin D and 1,000 mg/day calcium supplementation slightly, but significantly, reduced weight gain amounts in comparison with placebo in postmenopausal women, especially those with a baseline total calcium intake of less than 1,200 mg/day [[153](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en153)]. However, a meta-analysis of 12 vitamin D supplementation trials (including 5 in which body composition measurements were primary outcomes) found that vitamin D supplements without calorie restriction did not affect body weight or fat mass when the results were compared with those of placebo [[154](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en154)].

Overall, the available research suggests that consuming higher amounts of vitamin D or taking vitamin D supplements does not promote weight loss.

## Health Risks from Excessive Vitamin D

Excess amounts of vitamin D are toxic. Because vitamin D increases calcium absorption in the gastrointestinal tract, vitamin D toxicity results in marked hypercalcemia (total calcium greater than 11.1 mg/dL, beyond the normal range of 8.4 to 10.2 mg/dL), hypercalciuria, and high serum 25(OH)D levels (typically greater than 375 nmol/l [150 ng/mL]) [[155](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en155)]. Hypercalcemia, in turn, can lead to nausea, vomiting, muscle weakness, neuropsychiatric disturbances, pain, loss of appetite, dehydration, polyuria, excessive thirst, and kidney stones.

In extreme cases, vitamin D toxicity causes renal failure, calcification of soft tissues throughout the body (including in coronary vessels and heart valves), cardiac arrhythmias, and even death. Vitamin D toxicity has been caused by consumption of dietary supplements that contained excessive vitamin D amounts because of manufacturing errors, that were taken inappropriately or in excessive amounts, or that were incorrectly prescribed by physicians, [[155-157](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en155)].

Experts do not believe that excessive sun exposure results in vitamin D toxicity because thermal activation of previtamin D3 in the skin gives rise to various non-vitamin D forms that limit formation of vitamin D3. Some vitamin D3 is also converted to nonactive forms [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. However, frequent use of tanning beds, which provide artificial UV radiation, can lead to 25(OH)D levels well above 375–500 nmol/L (150–200 ng/mL) [[158-160](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en158)].

The combination of high intakes of calcium (about 2,100 mg/day from food and supplements) with moderate amounts of vitamin D (about 19 mcg [765 IU]/day from food and supplements) increased the risk of kidney stones by 17% over 7 years among 36,282 postmenopausal women who were randomly assigned to take 1,000 mg/day calcium and 10 mcg (400 IU)/day vitamin D or a placebo [[161](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en161)]. However, other, shorter (from 24 weeks to 5 years) clinical trials of vitamin D supplementation alone or with calcium in adults found greater risks of hypercalcemia and hypercalciuria, but not of kidney stones [[162](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en162),[163](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en163)].

The FNB established ULs for vitamin D in 2010 (Table 4) [[1](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)]. While acknowledging that signs and symptoms of toxicity are unlikely at daily intakes below 250 mcg (10,000 IU), the FNB noted that even vitamin D intakes lower than the ULs might have adverse health effects over time. The FNB recommended avoiding serum 25(OH)D levels above approximately 125–150 nmol/L (50–60 ng/mL), and it found that even lower serum levels (approximately 75–120 nmol/L [30–48 ng/mL]) are associated with increases in rates of all-cause mortality, risk of cancer at some sites (e.g., pancreas), risk of cardiovascular events, and number of falls and fractures among older adults.

| **Table 4: Tolerable Upper Intake Levels (ULs) for Vitamin D [**[**1**](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en1)**]** | | | | |
| --- | --- | --- | --- | --- |
| **Age** | **Male** | **Female** | **Pregnancy** | **Lactation** |
| 0–6 months | 25 mcg (1,000 IU) | 25 mcg (1,000 IU) |  |  |
| 7–12 months | 38 mcg (1,500 IU) | 38 mcg (1,500 IU) |  |  |
| 1–3 years | 63 mcg (2,500 IU) | 63 mcg (2,500 IU) |  |  |
| 4–8 years | 75 mcg (3,000 IU) | 75 mcg (3,000 IU) |  |  |
|  |  |  |  |  |
| 9–18 years | 100 mcg (4,000 IU) | 100 mcg (4,000 IU) | 100 mcg (4,000 IU) | 100 mcg (4,000 IU) |
| 19+ years | 100 mcg (4,000 IU) | 100 mcg (4,000 IU) | 100 mcg (4,000 IU) | 100 mcg (4,000 IU) |

## Interactions with Medications

Vitamin D supplements may interact with several types of medications. A few examples are provided below. Individuals taking these and other medications on a regular basis should discuss their vitamin D intakes and status with their health care providers.

### Orlistat

The weight-loss drug orlistat (Xenical and alli), together with a reduced-fat diet, can reduce the absorption of vitamin D from food and supplements, leading to lower 25(OH)D levels [[164-167](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en164)].

### Statins

Statin medications reduce cholesterol synthesis. Because endogenous vitamin D is derived from cholesterol, statins may also reduce vitamin D synthesis [[167](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en167)]. In addition, high intakes of vitamin D, especially from supplements, might reduce the potency of atorvastatin (Lipitor), lovastatin (Altoprev and Mevacor), and simvastatin (FloLipid and Zocor), because these statins and vitamin D appear to compete for the same metabolizing enzyme [[167-170](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en167)].

### Steroids

Corticosteroid medications, such as prednisone (Deltasone, Rayos, and Sterapred), are often prescribed to reduce inflammation. These medications can reduce calcium absorption and impair vitamin D metabolism [[171-173](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en171)]. In the NHANES 2001–2006 survey, 25(OH)D deficiency (less than 25 nmol/L [10 ng/mL]) was more than twice as common among children and adults who reported oral steroid use (11%) than in nonusers (5%) [[174](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en174)].

### Thiazide diuretics

Thiazide diuretics (e.g., Hygroton, Lozol, and Microzide) decrease urinary calcium excretion. The combination of these diuretics with vitamin D supplements (which increase intestinal calcium absorption) might lead to hypercalcemia, especially among older adults and individuals with compromised renal function or hyperparathyroidism [[167](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en167),[175](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en175),[176](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#en176)].

## Vitamin D and Healthful Diets

The federal government’s 2020–2025 Dietary Guidelines for Americans notes that “Because foods provide an array of nutrients and other components that have benefits for health, nutritional needs should be met primarily through foods. … In some cases, fortified foods and dietary supplements are useful when it is not possible otherwise to meet needs for one or more nutrients (e.g., during specific life stages such as pregnancy).”

For more information about building a healthy dietary pattern, refer to the [*Dietary Guidelines for Americans*](https://www.dietaryguidelines.gov/)*[external link disclaimer](https://ods.od.nih.gov/About/exit_disclaimer.aspx)* and the USDA’s [*MyPlate.*](https://www.choosemyplate.gov/)*[external link disclaimer](https://ods.od.nih.gov/About/exit_disclaimer.aspx)*

The Dietary Guidelines for Americans describes a healthy dietary pattern as one that

* Includes a variety of vegetables; fruits; grains (at least half whole grains); fat-free and low-fat milk, yogurt, and cheese; and oils.
  + Milk, many ready-to-eat cereals, and some brands of yogurt and orange juice are fortified with vitamin D. Cheese naturally contains small amounts of vitamin D. Vitamin D is added to some margarines.
* Includes a variety of protein foods such as lean meats; poultry; eggs; seafood; beans, peas, and lentils; nuts and seeds; and soy products.
  + ​​​​​​​Fatty fish, such as salmon, tuna, and mackerel, are very good sources of vitamin D. Beef liver and egg yolks have small amounts of vitamin D.
* ​​​​​​​Limits foods and beverages higher in added sugars, saturated fat, and sodium.
* Limits alcoholic beverages.
* Stays within your daily calorie needs.

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# Vitamin E

## Introduction

Vitamin E is found naturally in some foods, added to others, and available as a dietary supplement. Vitamin E is the collective name for a group of fat-soluble compounds with distinctive antioxidant activities [[1](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en1)].

Naturally occurring vitamin E exists in eight chemical forms (alpha-, beta-, gamma-, and delta-tocopherol and alpha-, beta-, gamma-, and delta-tocotrienol) that have varying levels of biological activity [[1](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en1)]. Alpha- (or α-) tocopherol is the only form that is recognized to meet human requirements.

Serum concentrations of vitamin E (alpha-tocopherol) depend on the liver, which takes up the nutrient after the various forms are absorbed from the small intestine. The liver preferentially resecretes only alpha-tocopherol via the hepatic alpha-tocopherol transfer protein [[1](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en1)]; the liver metabolizes and excretes the other vitamin E forms [[2](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en2)]. As a result, blood and cellular concentrations of other forms of vitamin E are lower than those of alpha-tocopherol and have been the subjects of less research [[3](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en3),[4](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en4)].

Antioxidants protect cells from the damaging effects of free radicals, which are molecules that contain an unshared electron. Free radicals damage cells and might contribute to the development of cardiovascular disease and cancer [[5](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en5)]. Unshared electrons are highly energetic and react rapidly with oxygen to form reactive oxygen species (ROS). The body forms ROS endogenously when it converts food to energy, and antioxidants might protect cells from the damaging effects of ROS. The body is also exposed to free radicals from environmental exposures, such as cigarette smoke, air pollution, and ultraviolet radiation from the sun. ROS are part of signaling mechanisms among cells.

Vitamin E is a fat-soluble antioxidant that stops the production of ROS formed when fat undergoes oxidation. Scientists are investigating whether, by limiting free-radical production and possibly through other mechanisms, vitamin E might help prevent or delay the chronic diseases associated with free radicals.

In addition to its activities as an antioxidant, vitamin E is involved in immune function and, as shown primarily by in vitro studies of cells, cell signaling, regulation of gene expression, and other metabolic processes [[1](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en1)]. Alpha-tocopherol inhibits the activity of protein kinase C, an enzyme involved in cell proliferation and differentiation in smooth muscle cells, platelets, and monocytes [[6](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en6)]. Vitamin-E-replete endothelial cells lining the interior surface of blood vessels are better able to resist blood cell components adhering to this surface. Vitamin E also increases the expression of two enzymes that suppress arachidonic acid metabolism, thereby increasing the release of prostacyclin from the endothelium, which, in turn, dilates blood vessels and inhibits platelet aggregation [[6](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en6)].

## Recommended Intakes

Intake recommendations for vitamin E and other nutrients are provided in the Dietary Reference Intakes (DRIs) developed by the Food and Nutrition Board (FNB) at the Institute of Medicine of The National Academies (formerly National Academy of Sciences) [[6](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en6)]. DRI is the general term for a set of reference values used to plan and assess nutrient intakes of healthy people. These values, which vary by age and gender, include the following:

* Recommended Dietary Allowance (RDA): Average daily level of intake sufficient to meet the nutrient requirements of nearly all (97%–98%) healthy individuals; often used to plan nutritionally adequate diets for individuals
* Adequate Intake (AI): Intake at this level is assumed to ensure nutritional adequacy; established when evidence is insufficient to develop an RDA
* Estimated Average Requirement (EAR): Average daily level of intake estimated to meet the requirements of 50% of healthy individuals; usually used to assess the nutrient intakes of groups of people and to plan nutritionally adequate diets for them; can also be used to assess the nutrient intakes of individuals
* Tolerable Upper Intake Level (UL): Maximum daily intake unlikely to cause adverse health effects

The FNB’s vitamin E recommendations are for alpha-tocopherol alone, the only form maintained in plasma. The FNB based these recommendations primarily on serum levels of the nutrient that provide adequate protection in a test measuring the survival of erythrocytes when exposed to hydrogen peroxide, a free radical [[6](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en6)]. Acknowledging great uncertainties in these data, the FNB has called for research to identify other biomarkers for assessing vitamin E requirements.

Naturally sourced vitamin E is called RRR-alpha-tocopherol (commonly labeled as d-alpha-tocopherol); the synthetically produced form is all rac-alpha-tocopherol (commonly labeled as dl-alpha-tocopherol).

RDAs for vitamin E are provided in milligrams (mg) and are listed in Table 1. One mg vitamin E (alpha-tocopherol) is equivalent to 1 mg RRR-alpha-tocopherol or 2 mg all rac-alpha-tocopherol. Because insufficient data are available to develop RDAs for infants, AIs were developed based on the amount of vitamin E consumed by healthy breastfed babies.

| **Table 1: Recommended Dietary Allowances (RDAs) for Vitamin E (Alpha-Tocopherol) [**[**6**](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en6)**]** | | | | |
| --- | --- | --- | --- | --- |
| **Age** | **Males** | **Females** | **Pregnancy** | **Lactation** |
| 0–6 months\* | 4 mg | 4 mg |  |  |
| 7–12 months\* | 5 mg | 5 mg |  |  |
| 1–3 years | 6 mg | 6 mg |  |  |
| 4–8 years | 7 mg | 7 mg |  |  |
| 9–13 years | 11 mg | 11 mg |  |  |
| 14+ years | 15 mg | 15 mg | 15 mg | 19 mg |

\*Adequate Intake (AI)

### International Units and Milligrams

Vitamin E is listed on the new Nutrition Facts and Supplement Facts labels in mg [[7](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en7)]. The U.S. Food and Drug Administration (FDA) required manufacturers to use these new labels starting in January 2020, but companies with annual sales of less than $10 million were allowed to use the old labels that list vitamin E in International Units (IUs) until January 2021 [[8](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en8)]. Conversion rules are as follows:

* To convert from mg to IU:
  + 1 mg of alpha-tocopherol is equivalent to 1.49 IU of the natural form or 2.22 IU of the synthetic form.
* To convert from IU to mg:
  + 1 IU of the natural form is equivalent to 0.67 mg of alpha-tocopherol.
  + ​​​​​​​1 IU of the synthetic form is equivalent to 0.45 mg of alpha-tocopherol.

For example, 15 mg of natural alpha-tocopherol would equal 22.4 IU (15 mg x 1.49 IU/mg = 22.4 IU). The corresponding value for synthetic alpha-tocopherol would be 33.3 IU (15 mg x 2.22 IU/mg).

## Sources of Vitamin E

### Food

Numerous foods provide vitamin E. Nuts, seeds, and vegetable oils are among the best sources of alpha-tocopherol, and significant amounts are available in green leafy vegetables and fortified cereals (see Table 2 for a more detailed list) [[9](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en9)]. Most vitamin E in American diets is in the form of gamma-tocopherol from soybean, canola, corn, and other vegetable oils and food products [[4](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en4)].

| **Table 2: Vitamin E (Alpha-Tocopherol) Content of Selected Foods [**[**9**](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en9)**]** | | |
| --- | --- | --- |
| **Food** | **Milligrams (mg) per serving** | **Percent DV\*** |
| Wheat germ oil, 1 tablespoon | 20.3 | 135 |
| Sunflower seeds, dry roasted, 1 ounce | 7.4 | 49 |
| Almonds, dry roasted, 1 ounce | 6.8 | 45 |
| Sunflower oil, 1 tablespoon | 5.6 | 37 |
| Safflower oil, 1 tablespoon | 4.6 | 31 |
| Hazelnuts, dry roasted, 1 ounce | 4.3 | 29 |
| Peanut butter, 2 tablespoons | 2.9 | 19 |
| Peanuts, dry roasted, 1 ounce | 2.2 | 15 |
| Corn oil, 1 tablespoon | 1.9 | 13 |
| Spinach, boiled, ½ cup | 1.9 | 13 |
| Broccoli, chopped, boiled, ½ cup | 1.2 | 8 |
| Soybean oil, 1 tablespoon | 1.1 | 7 |
| Kiwifruit, 1 medium | 1.1 | 7 |
| Mango, sliced, ½ cup | 0.7 | 5 |
| Tomato, raw, 1 medium | 0.7 | 5 |
| Spinach, raw, 1 cup | 0.6 | 4 |

\*DV = Daily Value. FDA developed DVs to help consumers compare the nutrient contents of foods and dietary supplements within the context of a total diet. The DV for vitamin E is 15 mg for adults and children age 4 years and older [[7](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en7)]. One mg vitamin E = 1 mg RRR-alpha-tocopherol = 2 mg all rac-alpha-tocopherol. FDA does not require food labels to list vitamin E content unless vitamin E has been added to the food. Foods providing 20% or more of the DV are considered to be high sources of a nutrient, but foods providing lower percentages of the DV also contribute to a healthful diet.

The U.S. Department of Agriculture’s (USDA’s) [FoodData Central](https://fdc.nal.usda.gov/)[external link disclaimer](https://ods.od.nih.gov/About/exit_disclaimer.aspx) website lists the nutrient content of many foods, including, in some cases, the amounts of alpha-, beta-, gamma-, and delta-tocopherol. The USDA also provides a comprehensive list of foods containing vitamin E arranged by [nutrient content](https://ods.od.nih.gov/pubs/usdandb/VitaminE-Content.pdf) and by [food name](https://ods.od.nih.gov/pubs/usdandb/VitaminE-Food.pdf).

### Dietary supplements

Supplements of vitamin E typically provide only alpha-tocopherol, although mixed products containing other tocopherols and even tocotrienols are available. Naturally occurring alpha-tocopherol exists in one stereoisomeric form. In contrast, synthetically produced alpha-tocopherol contains equal amounts of its eight possible stereoisomers; serum and tissues maintain only four of these stereoisomers [[6](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en6)]. A given amount of synthetic alpha-tocopherol (all rac-alpha-tocopherol; commonly labeled as DL or dl) is therefore only half as active as the same amount (by weight in mg) of the natural form (RRR-alpha-tocopherol; commonly labeled as D or d).

Most vitamin-E-only supplements provide ≥67 mg (100 IU of natural vitamin E) of the nutrient. These amounts are substantially higher than the RDAs.

Alpha-tocopherol in dietary supplements and fortified foods is often esterified to prolong its shelf life while protecting its antioxidant properties. The body hydrolyzes and absorbs these esters (alpha-tocopheryl acetate and succinate) as efficiently as alpha-tocopherol [[6](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en6)].

## Vitamin E Intakes and Status

Three national surveys—the 2001–2002 National Health and Nutrition Examination Survey (NHANES) [[10](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en10)], NHANES III (1988–1994) [[10](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en10)], and the Continuing Survey of Food Intakes by Individuals (1994–1996) [[11](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en11)]—have found that the diets of most Americans provide less than the RDA levels of vitamin E. These intake estimates might be low, however, because the amounts and types of fat added during cooking are often unknown and not accounted for [[6](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en6)].

The FNB suggests that mean intakes of vitamin E among healthy adults are probably higher than the RDA but cautions that low-fat diets might provide insufficient amounts unless people make their food choices carefully by, for example, increasing their intakes of nuts, seeds, fruits, and vegetables [[6](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en6),[10](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en10)]. The 1999–2000 NHANES found that 11.3% of adults took vitamin E supplements containing at least 400 IU [[12](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en12)].

## Vitamin E Deficiency

Frank vitamin E deficiency is rare and overt deficiency symptoms have not been found in healthy people who obtain little vitamin E from their diets [[6](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en6)]. Premature babies of very low birth weight (<1,500 grams) might be deficient in vitamin E. Vitamin E supplementation in these infants might reduce the risk of some complications, such as those affecting the retina, but they can also increase the risk of infections [[13](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en13)].

Because the digestive tract requires fat to absorb vitamin E, people with fat-malabsorption disorders are more likely to become deficient than people without such disorders. Deficiency symptoms include peripheral neuropathy, ataxia, skeletal myopathy, retinopathy, and impairment of the immune response [[6](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en6),[14](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en14)]. People with Crohn’s disease, cystic fibrosis, or an inability to secrete bile from the liver into the digestive tract, for example, often pass greasy stools or have chronic diarrhea; as a result, they sometimes require water-soluble forms of vitamin E, such as tocopheryl polyethylene glycol-1000 succinate [[1](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en1)].

Some people with abetalipoproteinemia, a rare inherited disorder resulting in poor absorption of dietary fat, require enormous doses of supplemental vitamin E (approximately 100 mg/kg or 5–10 g/day) [[1](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en1)]. Vitamin E deficiency secondary to abetalipoproteinemia causes such problems as poor transmission of nerve impulses, muscle weakness, and retinal degeneration that leads to blindness [[15](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en15)]. Ataxia and vitamin E deficiency (AVED) is another rare, inherited disorder in which the liver’s alpha-tocopherol transfer protein is defective or absent. People with AVED have such severe vitamin E deficiency that they develop nerve damage and lose the ability to walk unless they take large doses of supplemental vitamin E [[16](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en16)].

## Vitamin E and Health

Many claims have been made about vitamin E’s potential to promote health and prevent and treat disease. The mechanisms by which vitamin E might provide this protection include its function as an antioxidant and its roles in anti-inflammatory processes, inhibition of platelet aggregation, and immune enhancement.

A primary barrier to characterizing the roles of vitamin E in health is the lack of validated biomarkers for vitamin E intake and status to help relate intakes to valid predictors of clinical outcomes [[6](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en6)]. This section focuses on four diseases and disorders in which vitamin E might be involved: heart disease, cancer, eye disorders, and cognitive decline.

### Coronary heart disease

Evidence that vitamin E could help prevent or delay coronary heart disease (CHD) comes from several sources. In vitro studies have found that the nutrient inhibits oxidation of low-density lipoprotein (LDL) cholesterol, thought to be a crucial initiating step for atherosclerosis [[6](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en6)]. Vitamin E might also help prevent the formation of blood clots that could lead to a heart attack or venous thromboembolism [[17](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en17)].

Several observational studies have associated lower rates of heart disease with higher vitamin E intakes. One study of approximately 90,000 nurses found that the incidence of heart disease was 30% to 40% lower in those with the highest intakes of vitamin E, primarily from supplements [[18](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en18)]. Among a group of 5,133 Finnish men and women followed for a mean of 14 years, higher vitamin E intakes from food were associated with decreased mortality from CHD [[19](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en19)].

However, randomized clinical trials cast doubt on the efficacy of vitamin E supplements to prevent CHD [[20](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en20)]. For example, the Heart Outcomes Prevention Evaluation (HOPE) study, which followed almost 10,000 patients at high risk of heart attack or stroke for 4.5 years [[21](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en21)], found that participants taking 400 IU/day of natural vitamin E (268 mg) experienced no fewer cardiovascular events or hospitalizations for heart failure or chest pain than participants taking a placebo. In the HOPE-TOO follow-up study, almost 4,000 of the original participants continued to take vitamin E or placebo for an additional 2.5 years [[22](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en22)]. HOPE-TOO found that vitamin E provided no significant protection against heart attacks, strokes, unstable angina, or deaths from cardiovascular disease or other causes after 7 years of treatment. Participants taking vitamin E, however, were 13% more likely to experience, and 21% more likely to be hospitalized for, heart failure, a statistically significant but unexpected finding not reported in other large studies.

The HOPE and HOPE-TOO trials provide compelling evidence that moderately high doses of vitamin E supplements do not reduce the risk of serious cardiovascular events among men and women >50 years of age with established heart disease or diabetes [[23](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en23)]. These findings are supported by evidence from the Women’s Angiographic Vitamin and Estrogen study, in which 423 postmenopausal women with some degree of coronary stenosis took supplements with 400 IU vitamin E (form not specified) and 500 mg vitamin C twice a day or placebo for >4 years [[24](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en24)]. Not only did the supplements provide no cardiovascular benefits, but all-cause mortality was significantly higher in the women taking the supplements.

The latest published clinical trial of vitamin E’s effects on the heart and blood vessels of women included almost 40,000 healthy women ≥45 years of age who were randomly assigned to receive either 600 IU of natural vitamin E (402 mg) on alternate days or placebo and who were followed for an average of 10 years [[25](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en25)]. The investigators found no significant differences in rates of overall cardiovascular events (combined nonfatal heart attacks, strokes, and cardiovascular deaths) or all-cause mortality between the groups. However, the study did find two positive and significant results for women taking vitamin E: they had a 24% reduction in cardiovascular death rates, and those ≥65 years of age had a 26% decrease in nonfatal heart attack and a 49% decrease in cardiovascular death rates.

The most recent published clinical trial of vitamin E and men’s cardiovascular health included almost 15,000 healthy physicians ≥50 years of age who were randomly assigned to receive 400 IU synthetic alpha-tocopherol (180 mg) every other day, 500 mg vitamin C daily, both vitamins, or placebo [[26](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en26)]. During a mean follow-up period of 8 years, intake of vitamin E (and/or vitamin C) had no effect on the incidence of major cardiovascular events, myocardial infarction, stroke, or cardiovascular morality. Furthermore, use of vitamin E was associated with a significantly increased risk of hemorrhagic stroke.

In general, clinical trials have not provided evidence that routine use of vitamin E supplements prevents cardiovascular disease or reduces its morbidity and mortality. However, participants in these studies have been largely middle-aged or elderly individuals with demonstrated heart disease or risk factors for heart disease. Some researchers have suggested that understanding the potential utility of vitamin E in preventing CHD might require longer studies in younger participants taking higher doses of the supplement [[27](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en27)]. Further research is needed to determine whether supplemental vitamin E has any protective value for younger, healthier people at no obvious risk of CHD.

### Cancer

Antioxidant nutrients like vitamin E protect cell constituents from the damaging effects of free radicals that, if unchecked, might contribute to cancer development [[9](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en9)]. Vitamin E might also block the formation of carcinogenic nitrosamines formed in the stomach from nitrites in foods and protect against cancer by enhancing immune function [[28](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en28)]. Unfortunately, human trials and surveys that have attempted to associate vitamin E intake with cancer incidence have found that vitamin E is not beneficial in most cases.

Both the HOPE-TOO Trial and Women’s Health Study evaluated whether vitamin E supplements might protect people from cancer. HOPE-TOO, which followed men and women ≥55 years of age with heart disease or diabetes for 7 years, found no significant differences in the number of new cancers or cancer deaths between individuals randomly assigned to take 400 IU/day of natural vitamin E (268 mg) or a placebo [[22](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en22)]. In the Women’s Health Study, in which healthy women ≥45 years of age received either 600 IU of natural vitamin E (402 mg) every other day or a placebo for 10 years, the supplement did not reduce the risk of developing any form of cancer [[25](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en25)].

Several studies have examined whether vitamin E intake and/or supplemental vitamin E affects the risk of developing prostate cancer. A prospective cohort study of >29,000 men found no association between dietary or supplemental vitamin E intake and prostate cancer risk [[29](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en29)]. However, among current smokers and men who had quit, vitamin E intakes of more than 400 IU/day (form not specified) were associated with a statistically significant 71% reduction in the risk of advanced prostate cancer. In a clinical trial involving 29,133 male smokers, men randomly assigned to take daily supplements of 111 IU of synthetic vitamin E (50 mg, as dl-alpha-tocopheryl acetate) for 5–8 years had 32% fewer prostate cancers compared to subjects who did not take the supplements [[30](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en30)]. Based in part on the promising results of this study, a large randomized clinical trial, called the SELECT trial, began in 2001 to determine whether 7–12 years of daily supplementation with 400 IU of synthetic vitamin E (180 mg, as dl-alpha-tocopheryl acetate), with or without selenium (200 mcg, as L-selenomethionine), reduced the number of new prostate cancers in 35,533 healthy men age 50 and older. The trial was discontinued in October 2008 when an analysis found that the supplements, taken alone or together for about 5.5 years, did not prevent prostate cancer [[31](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en31)]. Results from an additional 1.5 years of follow-up from this trial (during which the subjects no longer received vitamin E or selenium), showed that the men who had taken the vitamin E had a 17% increased risk of prostate cancer compared to men only taking placebos, a statistically significant difference [[32](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en32)]. The risk of developing prostate cancer was also slightly increased in subjects taking vitamin E plus selenium or selenium alone, but the differences were not statistically significant. No differences were found among groups in the incidence of lung or colorectal cancers or all cancers combined. Study staff members will continue to monitor participants’ health for up to 5 more years. The National Cancer Institute website provides [additional information on the SELECT trial](http://www.cancer.gov/newscenter/qa/2008/selectqa)[external link disclaimer](https://ods.od.nih.gov/About/exit_disclaimer.aspx).

One study of women in Iowa provides evidence that higher intakes of vitamin E from foods and supplements could decrease the risk of colon cancer, especially in women <65 years of age [[33](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en33)]. The overall relative risk for the highest quintile of intake (>35.7 IU/day, form not specified) compared to the lowest quintile (<5.7 IU/day, form not specified) was 0.32. However, prospective cohort studies of 87,998 women in the Nurses’ Health Study and 47,344 men in the Health Professionals Follow-up Study failed to replicate these results [[34](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en34)]. Although some research links higher intakes of vitamin E with decreased incidence of breast cancer, an examination of the impact of dietary factors, including vitamin E, on the incidence of postmenopausal breast cancer in >18,000 women found no benefit from the vitamin [[35](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en35)].

The American Cancer Society conducted an epidemiologic study examining the association between use of vitamin C and vitamin E supplements and bladder cancer mortality. Of the almost one million adults followed between 1982 and 1998, adults who took supplemental vitamin E for 10 years or longer had a reduced risk of death from bladder cancer [[36](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en36)]; vitamin C supplementation provided no protection.

Evidence to date is insufficient to support taking vitamin E to prevent cancer. In fact, daily use of large-dose vitamin E supplements (400 IU of synthetic vitamin E [180 mg]) may increase the risk of prostate cancer.

### Eye disorders

Age-related macular degeneration (AMD) and cataracts are among the most common causes of significant vision loss in older people. Their etiologies are usually unknown, but the cumulative effects of oxidative stress have been postulated to play a role. If so, nutrients with antioxidant functions, such as vitamin E, could be used to prevent or treat these conditions.

Prospective cohort studies have found that people with relatively high dietary intakes of vitamin E (e.g., 20 mg/day [30 IU]) have an approximately 20% lower risk of developing AMD than people with low intakes (e.g., <10 mg/day [<15 IU]) [[37](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en37),[38](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en38)]. However, two randomized controlled trials in which participants took supplements of vitamin E (500 IU/day [335 mg] d-alpha-tocopherol in one study [[39](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en39)] and 111 IU/day (50 mg) dl-alpha-tocopheryl acetate combined with 20 mg/day beta-carotene in the other [[40](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en40)]) or a placebo failed to show a protective effect for vitamin E on AMD. The Age-Related Eye Disease Study (AREDS), a large randomized clinical trial, found that participants at high risk of developing advanced AMD (i.e., those with intermediate AMD or those with advanced AMD in one eye) reduced their risk of developing advanced AMD by 25% by taking a daily supplement containing vitamin E (400 IU [180 mg] dl-alpha-tocopheryl acetate), beta-carotene (15 mg), vitamin C (500 mg), zinc (80 mg), and copper (2 mg) compared to participants taking a placebo over 5 years [[41](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en41)]. A follow-up AREDS2 study confirmed the value of this and similar supplement formulations in reducing the progression of AMD over a median follow-up period of 5 years [[42](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en42)].

Several observational studies have revealed a potential relationship between vitamin E supplements and the risk of cataract formation. One prospective cohort study found that lens clarity was superior in participants who took vitamin E supplements and those with higher blood levels of the vitamin [[43](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en43)]. In another study, long-term use of vitamin E supplements was associated with slower progression of age-related lens opacification [[44](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en44)]. However, in the AREDS trial, the use of a vitamin E-containing (as dl-alpha-tocopheryl acetate) formulation had no apparent effect on the development or progression of cataracts over an average of 6.3 years [[45](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en45)]. The AREDS2 study, which also tested formulations containing 400 IU (180 mg) vitamin E, confirmed these findings [[46](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en46)].

Overall, the available evidence is inconsistent with respect to whether vitamin E supplements, taken alone or in combination with other antioxidants, can reduce the risk of developing AMD or cataracts. However, the formulations of vitamin E, other antioxidants, zinc, and copper used in AREDS hold promise for slowing the progression of AMD in people at high risk of developing advanced AMD.

### Cognitive decline

The brain has a high oxygen consumption rate and abundant polyunsaturated fatty acids in the neuronal cell membranes. Researchers hypothesize that if cumulative free-radical damage to neurons over time contributes to cognitive decline and neurodegenerative diseases, such as Alzheimer’s disease, then ingestion of sufficient or supplemental antioxidants (such as vitamin E) might provide some protection [[47](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en47)]. This hypothesis was supported by the results of a clinical trial in 341 patients with Alzheimer’s disease of moderate severity who were randomly assigned to receive a placebo, vitamin E (2,000 IU/day dl-alpha-tocopherol), a monoamine oxidase inhibitor (selegiline), or vitamin E and selegiline [[47](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en47)]. Over 2 years, treatment with vitamin E and selegiline, separately or together, significantly delayed functional deterioration and the need for institutionalization compared to placebo. However, participants taking vitamin E experienced significantly more falls.

Vitamin E consumption from foods or supplements was associated with less cognitive decline over 3 years in a prospective cohort study of elderly, free-living individuals age 65–102 years [[48](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en48)]. However, a clinical trial in primarily healthy older women who were randomly assigned to receive 600 IU (402 mg) d-alpha-tocopherol every other day or a placebo for ≤4 years found that the supplements provided no apparent cognitive benefits [[49](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en49)]. Another trial in which 769 men and women with mild cognitive impairment were randomly assigned to receive 2,000 IU/day vitamin E (form not specified), a cholinesterase inhibitor (donepezil), or placebo found no significant differences in the progression rate of Alzheimer’s disease between the vitamin E and placebo groups [[50](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en50)]

In summary, most research results do not support the use of vitamin E supplements by healthy or mildly impaired individuals to maintain cognitive performance or slow its decline with normal aging [[51](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en51)]. More research is needed to identify the role of vitamin E, if any, in the management of cognitive impairment [[52](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en52)].

## Health Risks from Excessive Vitamin E

Research has not found any adverse effects from consuming vitamin E in food [[6](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en6)]. However, high doses of alpha-tocopherol supplements can cause hemorrhage and interrupt blood coagulation in animals, and in vitro data suggest that high doses inhibit platelet aggregation. Two clinical trials have found an increased risk of hemorrhagic stroke in participants taking alpha-tocopherol; one trial included Finnish male smokers who consumed 50 mg/day for an average of 6 years [[53](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en53)] and the other trial involved a large group of male physicians in the United States who consumed 400 IU (180 mg) of synthetic vitamin E every other day for 8 years [[26](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en26)]. Because the majority of physicians in the latter study were also taking aspirin, this finding could indicate that vitamin E has a tendency to cause bleeding.

The FNB has established ULs for vitamin E based on the potential for hemorrhagic effects (see Table 3). The ULs apply to all forms of supplemental alpha-tocopherol, including the eight stereoisomers present in synthetic vitamin E. Doses of up to 1,000 mg/day (1,500 IU/day of the natural form or 1,100 IU/day of the synthetic form) in adults appear to be safe, although the data are limited and based on small groups of people taking up to 3,200 mg/day of alpha-tocopherol for only a few weeks or months. Long-term intakes above the UL increase the risk of adverse health effects [[6](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en6)]. Vitamin E ULs for infants have not been established.

| **Table 3: Tolerable Upper Intake Levels (ULs) for Vitamin E [**[**6**](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en6)**]** | | | | |
| --- | --- | --- | --- | --- |
| **Age** | **Male** | **Female** | **Pregnancy** | **Lactation** |
| 1–3 years | 200 mg | 200 mg |  |  |
| 4–8 years | 300 mg | 300 mg |  |  |  |
| 9–13 years | 600 mg | 600 mg |  |  |  |
| 14–18 years | 800 mg | 800 mg | 800 mg | 800 mg |  |
| 19+ years | 1,000 mg | 1,000 mg | 1,000 mg | 1,000 mg |  |

Two meta-analyses of randomized trials have also raised questions about the safety of large doses of vitamin E, including doses lower than the UL. These meta-analyses linked supplementation to small but statistically significant increases in all-cause mortality. One analysis found an increased risk of death at doses of 400 IU/day (form not specified), although the risk began to increase at 150 IU [[54](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en54)]. In the other analysis of studies of antioxidant supplements for disease prevention, the highest quality trials revealed that vitamin E, administered singly (dose range 10 IU–5,000 IU/day; mean 569 IU [form not specified]) or combined with up to four other antioxidants, significantly increased mortality risk [[55](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en55)].

The implications of these analyses for the potential adverse effects of high-dose vitamin E supplements are unclear [[56-59](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en56)]. Participants in the studies included in these analyses were typically middle-aged or older and had chronic diseases or related risk factors. These participants often consumed other supplements in addition to vitamin E. Some of the studies analyzed took place in developing countries in which nutritional deficiencies are common. A review of the subset of studies in which vitamin E supplements were given to healthy individuals for the primary prevention of chronic disease found no convincing evidence that the supplements increased mortality [[60](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en60)].

However, results from the recently published, large SELECT trial show that vitamin E supplements (400 IU/day [180 mg] as dl-alpha-tocopheryl acetate) may harm adult men in the general population by increasing their risk of prostate cancer [[32](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en32)]. Follow-up studies are assessing whether the cancer risk was associated with baseline blood levels of vitamin E and selenium prior to supplementation as well as whether changes in one or more genes might increase a man’s risk of developing prostate cancer while taking vitamin E.

## Interactions with Medications

Vitamin E supplements have the potential to interact with several types of medications. A few examples are provided below. People taking these and other medications on a regular basis should discuss their vitamin E intakes with their health care providers.

### Anticoagulant and antiplatelet medications

Vitamin E can inhibit platelet aggregation and antagonize vitamin K-dependent clotting factors. As a result, taking large doses with anticoagulant or antiplatelet medications, such as warfarin (Coumadin), can increase the risk of bleeding, especially in conjunction with low vitamin K intake. The amounts of supplemental vitamin E needed to produce clinically significant effects are unknown but probably exceed 400 IU/day [[61](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en61)].

### Simvastatin and niacin

Some people take vitamin E supplements with other antioxidants, such as vitamin C, selenium, and beta-carotene. This collection of antioxidant ingredients blunted the rise in high-density lipoprotein (HDL) cholesterol levels, especially levels of HDL2, the most cardioprotective HDL component, among people treated with a combination of simvastatin (brand name Zocor) and niacin [[62](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en62),[63](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en63)].

### Chemotherapy and radiotherapy

Oncologists generally advise against the use of antioxidant supplements during cancer chemotherapy or radiotherapy because they might reduce the effectiveness of these therapies by inhibiting cellular oxidative damage in cancerous cells [[64](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en64),[65](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en65)]. Although a systematic review of randomized controlled trials has called this concern into question [[66](https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/#en66)], further research is needed to evaluate the potential risks and benefits of concurrent antioxidant supplementation with conventional therapies for cancer.

## Vitamin E and Healthful Diets

The federal government’s 2020–2025 Dietary Guidelines for Americans notes that “Because foods provide an array of nutrients and other components that have benefits for health, nutritional needs should be met primarily through foods. … In some cases, fortified foods and dietary supplements are useful when it is not possible otherwise to meet needs for one or more nutrients (e.g., during specific life stages such as pregnancy).”

For more information about building a healthy dietary pattern, refer to the [*Dietary Guidelines for Americans*](https://www.dietaryguidelines.gov/)*[external link disclaimer](https://ods.od.nih.gov/About/exit_disclaimer.aspx)* and the USDA’s [*MyPlate.*](https://www.choosemyplate.gov/)*[external link disclaimer](https://ods.od.nih.gov/About/exit_disclaimer.aspx)*

The Dietary Guidelines for Americans describes a healthy dietary pattern as one that

* Includes a variety of vegetables; fruits; grains (at least half whole grains); fat-free and low-fat milk, yogurt, and cheese; and oils.
  + ​​​​​​​Vitamin E is found in green leafy vegetables, whole grains, fortified cereals, and vegetable oils.
* Includes a variety of protein foods such as lean meats; poultry; eggs; seafood; beans, peas, and lentils; nuts and seeds; and soy products.
  + ​​​​​​​Nuts are good sources of vitamin E.
* Limits foods and beverages higher in added sugars, saturated fat, and sodium.
* Limits alcoholic beverages.
* Stays within your daily calorie needs.

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# Eye Conditions at a Glance

Vision problems affect many Americans. More than 3.4 million aged 40 and older are blind or visually impaired. However, some estimates suggest that as many as 21 million Americans have vision problems and that 80 million have potentially blinding eye diseases. Age-related macular degeneration, cataract, diabetic retinopathy, and glaucoma are the main causes of visual impairment and blindness in older Americans. Conventional treatments, such as surgery, are available for some eye conditions, but some people turn to dietary supplements to prevent them or to delay their progression.

## What the Science Says

### **Age-Related Macular Degeneration**

Age-Related Macular Degeneration (AMD) is a leading cause of vision loss in people aged 50 and older. It destroys the macula, the part of the eye that provides sharp, central vision needed for clearly seeing objects directly in front of you. No treatments exist for early AMD, but conventional treatment is available for advanced AMD, which may help stop further vision loss. The National Institutes of Health sponsored a major study with almost 4,800 adults (2001) called the [Age-Related Eye Disease Study (AREDS)](https://www.nei.nih.gov/research/clinical-trials/age-related-eye-disease-studies-aredsareds2), which looked at the effects of a dietary supplement on the progression of AMD, and a second study (2013), [Age-Related Eye Disease Study 2 (AREDS2)](https://www.nei.nih.gov/research/clinical-trials/age-related-eye-disease-studies-aredsareds2), which tested changes to this dietary supplement. More than 4,000 people aged 50–85 years participated in AREDS2.

* AREDS showed that a dietary supplement containing high doses of vitamins C and E, beta-carotene, zinc, and copper can help slow the progression of AMD. However, during the period when this study was performed, other research showed that taking beta-carotene supplements increases the risk of lung cancer in people who smoke cigarettes.
* AREDS2 investigated several modifications of the original AREDS supplement formula in people with AMD who were at risk for progressing to the advanced stage of the disease. Participants were randomly assigned to groups that received the original formula or various modified versions. The modifications included removing beta-carotene, reducing the amount of zinc, adding omega-3 fatty acids (fish oil), and adding lutein and zeaxanthin (two carotenoids that are found in the eye). Current smokers were not assigned to groups that received beta-carotene because of the known risk of lung cancer, but some nonsmokers and former smokers did receive beta-carotene.
  + Adding omega-3 fatty acids (fish oil) did not improve the effectiveness of the supplement combination.
  + Reducing the amount of zinc from the supplement combination did not decrease its effectiveness.
  + People who took beta-carotene were more likely to develop lung cancer than those who did not take it. Most of the cases of lung cancer occurred in former smokers. Lutein and zeaxanthin did not increase lung cancer risk.
  + After 10 years of follow-up, lutein and zeaxanthin proved to be more effective than beta-carotene in reducing the risk of progression to advanced AMD.
* A 2015 systematic review of two randomized controlled trials involving 2,343 participants found that omega-3 fatty acid supplementation in people with AMD for periods up to 5 years does not reduce the risk of progression to advanced AMD or the development of moderate to severe visual loss.
* Several studies conducted in the United States, Europe, or Australia have shown associations between dietary patterns and AMD. In general, Mediterranean dietary patterns or other dietary patterns high in vegetables and fruits and low in red meat have been linked with lower rates of advanced AMD. Dietary patterns have not been consistently associated with early AMD.

### **Cataracts**

A cataract occurs when the lens of the eye becomes clouded, causing blurring or discoloration of vision. If vision loss from a cataract becomes severe enough to interfere with normal activities, surgery to remove the lens and replace it with an artificial one often helps.

* Findings from a 2015 randomized controlled trial of 11,267 men from the Selenium and Vitamin E Cancer Prevention Trial (SELECT) Eye Endpoints Study indicate that long-term daily supplementation with selenium and/or vitamin E is unlikely to have a large beneficial effect on age-related cataract.
* A 2014 Swedish epidemiologic study that included about 30,600 women looked at potential associations between antioxidant consumption and cataract formation. The study concluded that consuming antioxidants through diet may lower the risk of cataract formation.
* However, a 2012 review article that included 9 clinical trials with almost 117,300 people determined that supplementing with the [antioxidants](https://www.nccih.nih.gov/health/antioxidants-in-depth) vitamins C and E and beta-carotene does not prevent cataracts or slow their progression.
* Results from AREDS2 showed that none of the modified formulations helped reduce the risk of progression to cataract surgery, although a subgroup of participants with low dietary lutein and zeaxanthin gained some protection.

### **Diabetic Retinopathy**

In diabetic retinopathy, an eye disease that occurs as a complication of [diabetes](https://www.nccih.nih.gov/health/diabetes-and-dietary-supplements), the blood vessels of the retina become damaged. This can cause vision distortion or loss.

* A 2011 literature review stated that no dietary supplements have been shown to be helpful for diabetic retinopathy.

### **Glaucoma**

Glaucoma can damage the optic nerve, resulting in a loss of vision, starting with peripheral (side) vision. Early detection and treatment of glaucoma are important. There is little evidence to support using megavitamins, special diets, acupuncture, relaxation techniques, or therapeutic touch for glaucoma.

## Side Effects and Risks

* It’s important to follow your eye care professional’s instructions for treating eye conditions. Don’t use unproven approaches to replace conventional medical treatments.
* Supplements containing certain antioxidants and zinc are recommended only for some people with AMD. For example, they are not recommended for those with early-stage AMD. If you have AMD, ask your eye care professional whether taking supplements is advisable.
* Beta-carotene (which is in AREDS but not AREDS2 formulations) may increase the risk of lung cancer in current and former smokers and those who have been exposed to asbestos.
* Keep in mind that dietary supplements can cause health problems if not used correctly or if used in large amounts, and some may interact with medications you take.

For more information on eye health, visit the [National Eye Institute (NEI) website](https://www.nei.nih.gov/learn-about-eye-health).

## For More Information

### **NCCIH Clearinghouse**

The NCCIH Clearinghouse provides information on NCCIH and complementary and integrative health approaches, including publications and searches of Federal databases of scientific and medical literature. The Clearinghouse does not provide medical advice, treatment recommendations, or referrals to practitioners.

**Toll-free in the U.S.:**1-888-644-6226

**Telecommunications relay service (TRS):**7-1-1

**Website:**[https://www.nccih.nih.gov](https://www.nccih.nih.gov/)

**Email:**[info@nccih.nih.gov](mailto:info@nccih.nih.gov)(link sends email)

### **Know the Science**

NCCIH and the National Institutes of Health (NIH) provide tools to help you understand the basics and terminology of scientific research so you can make well-informed decisions about your health. [Know the Science](https://www.nccih.nih.gov/health/know-science) features a variety of materials, including interactive modules, quizzes, and videos, as well as links to informative content from Federal resources designed to help consumers make sense of health information.

[Explaining How Research Works](https://www.nih.gov/about-nih/what-we-do/science-health-public-trust/perspectives/explaining-how-research-works) (NIH)

[Know the Science: How To Make Sense of a Scientific Journal Article](https://www.nccih.nih.gov/health/know-science/how-to-make-sense-of-a-scientific-journal-article/overview)

[Understanding Clinical Studies](https://www.nih.gov/about-nih/what-we-do/science-health-public-trust/perspectives/understanding-clinical-studies) (NIH)

### **PubMed®**

A service of the National Library of Medicine, PubMed® contains publication information and (in most cases) brief summaries of articles from scientific and medical journals. For guidance from NCCIH on using PubMed, see [How To Find Information About Complementary Health Approaches on PubMed](https://nccih.nih.gov/health/find-information-about-complementary-health-approaches-pubmed).

**Website:**<https://pubmed.ncbi.nlm.nih.gov/>

## What is it?

Hops are the dried, flowering parts of the hop plant (Humulus lupulus), commonly used in brewing beer. They have limited evidence of health benefits.  
  
The term "hops" comes from the Anglo-Saxon term "hoppan", which means "to climb." Hops contain many chemicals, including bitter acids, which contribute to its bitter flavor. Some chemicals in hops seem to act similarly to the hormone estrogen and some seem to cause sleepiness.  
  
People commonly use hops for anxiety, sleep disorders, restlessness, symptoms of menopause, and many other conditions, but there is no good scientific evidence to support these uses.

## How effective is it?

There is interest in using hops for a number of purposes, but there isn't enough reliable information to say whether it might be helpful.

## Is it safe?

**When taken by mouth**: Hops are commonly consumed in foods. Hops extracts and hops bitter acids are possibly safe when used short-term. Hops extracts have been used safely in doses of up to 300 mg daily for up to 3 months. Hops bitter acids have been used safely in doses of 35 mg daily for 3 months. Hops might cause dizziness and sleepiness in some people.

#### Special precautions & warnings:

**Pregnancy and breast-feeding**: There isn't enough reliable information to know if hops are safe to use when pregnant or breast-feeding. Stay on the safe side and avoid use.  
  
**Hormone sensitive cancers and conditions**: Some chemicals in hops act like the hormone estrogen. People who have conditions that are sensitive to estrogen should use caution when taking hops. Some of these conditions include breast cancer and endometriosis.  
  
**Surgery**: Hops might cause too much sleepiness when combined with anesthesia and other medications during and after surgical procedures. Stop taking hops at least 2 weeks before a scheduled surgery.

## Are there interactions with medications?

**Moderate**

**Be cautious with this combination.**

**Estrogens**

Hops might have some of the same effects as estrogen. Taking hops along with estrogen might decrease the effects of estrogen.

**Medications changed by the liver (Cytochrome P450 1A2 (CYP1A2) substrates)**

Some medications are changed and broken down by the liver. Hops might change how quickly the liver breaks down these medications. This could change the effects and side effects of these medications.

**Medications changed by the liver (Cytochrome P450 3A4 (CYP3A4) substrates)**

Some medications are changed and broken down by the liver. Hops might change how quickly the liver breaks down these medications. This could change the effects and side effects of these medications.

**Sedative medications (CNS depressants)**

Hops might cause sleepiness and slowed breathing. Some medications, called sedatives, can also cause sleepiness and slowed breathing. Taking hops with sedative medications might cause breathing problems and/or too much sleepiness.

## Are there interactions with herbs and supplements?

**Herbs and supplements with sedative properties**

Hops might cause sleepiness and slowed breathing. Taking it along with other supplements with similar effects might cause too much sleepiness and/or slowed breathing in some people. Examples of supplements with this effect include kava, L-tryptophan, melatonin, and valerian.

**Herbs that might act like estrogen**

Hops might have the same effects as estrogen. Using it along with other supplements with similar effects might increase estrogen-like effects and side effects. Examples of supplements with this effect include black cohosh, kudzu, peony, and red clover.

## Are there interactions with foods?

There are no known interactions with foods.

## How is it typically used?

Hops are available in many different types of products, including beverages, tablets, capsules, creams, and gels. There isn't enough reliable information to know what an appropriate dose of hops might be. Keep in mind that natural products are not always necessarily safe and dosages can be important. Be sure to follow relevant directions on product labels and consult a healthcare professional before using.

## Other names

Asperge Sauvage, Common Hops, Couleuvrée, Couleuvrée Septentrionale, European Hops, Hop, Hop Strobile, Hopfenzapfen, Houblon, Humulus lupulus, Lupuli Strobulus, Lupulin, Lúpulo, Pi Jiu Hua, Salsepareille Indigène, Vigne du Nord.

## Methodology

To learn more about how this article was written, please see the *Natural Medicines Comprehensive Database* [methodology](https://medlineplus.gov/druginfo/natural/methodology.html).

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