

Fat-Soluble Vitamins: A, D, E, and K

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What are Vitamins?

Vitamins are essential micronutrients required by the body in small amounts to support a range of vital functions. Vitamins are divided into two groups: water-soluble (B-complex vitamins and C vitamins) and fat-soluble vitamins (A, D, E and K). Unlike water-soluble vitamins that need regular replacement in the body, fat-soluble vitamins are stored in the liver and fatty tissues, and are eliminated much more slowly than water-soluble vitamins. For more information on water-soluble vitamins, see fact sheet [9.312 Water-Soluble Vitamins: Vitamin B-Complex and Vitamin C](#).

What are Fat-Soluble Vitamins?

The fat-soluble vitamins, A, D, E, and K, are stored in the body for long periods of time and generally pose a greater risk for toxicity than water-soluble vitamins when consumed in excess. Eating a normal, well-balanced diet will not lead to toxicity in otherwise healthy individuals. However, taking vitamin supplements that contain megadoses of vitamins A, D, E and K may lead to toxicity.

While diseases caused by a lack of fat-soluble vitamins are rare in the United States, symptoms of mild deficiency can develop without adequate amounts of vitamins in the diet. Additionally, some health problems, such as inflammatory bowel disease (IBD), chronic pancreatitis, and cystic fibrosis, may decrease the absorption of fat, and in turn, decrease the absorption of vitamins A, D, E and K. Consult a medical professional about

any potential health problems that may interfere with vitamin absorption.

Vitamin A: Retinol

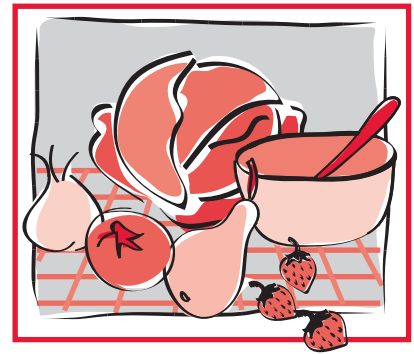
What is Vitamin A?

Vitamin A, also called retinol, has many functions in the body. In addition to helping the eyes adjust to light changes, vitamin A plays an important role in bone growth, tooth development, reproduction, cell division, gene expression, and regulation of the immune system. The skin, eyes, and mucous membranes of the mouth, nose, throat and lungs depend on vitamin A to remain moist. Vitamin A is also an important antioxidant that may play a role in the prevention of certain cancers.



Food Sources for Vitamin A

Eating a wide variety of foods is the best way to ensure that the body gets enough vitamin A. The retinol, retinal, and retinoic acid forms of vitamin A are supplied primarily by foods of animal origin such as dairy products, fish and liver. Some foods of plant origin contain the antioxidant, beta-carotene, which the body converts to vitamin A. Beta-carotene, comes from fruits and vegetables, especially those that are orange or dark green in color. Vitamin A sources also include carrots, pumpkin, winter squash, dark green leafy vegetables and apricots, all of which are rich in beta-carotene.



Quick Facts

- Small amounts of vitamin A, vitamin D, vitamin E and vitamin K are needed to maintain good health.
- Fat-soluble vitamins will not be lost when the foods that contain them are cooked.
- The body does not need these vitamins every day and stores them in the liver and adipose (fat) tissue when not used.
- Most people do not need vitamin supplements.
- Megadoses of vitamins A, D, E or K can be toxic and lead to health problems.
- Requirements for vitamins may be expressed in different mathematical units. Close attention should be paid to ensure that similar units are being compared.

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How Much Vitamin A Do We Need?

The recommendation for vitamin A intake is expressed as micrograms (mcg) of retinol activity equivalents (RAE). Retinol activity equivalents account for the fact that the body converts only a portion of beta-carotene to retinol. One RAE equals 1 mcg of retinol or 12 mcg of beta-carotene (Table 1). The Recommended Dietary Allowance (RDA) for vitamin A is 900 mcg/day for adult males and 700 mcg/day for adult females.

Compared to vitamin A containing foods, it takes twice the amount of carotene rich foods to meet the body's vitamin A requirements, so one may need to increase consumption of carotene containing plant foods to meet the RDA for vitamin A.

Studies indicate that vitamin A requirements may be increased due to hyperthyroidism, fever, infection, cold, and exposure to excessive amounts of sunlight. Those who consume excess alcohol or have renal disease should also increase intake of vitamin A.

Vitamin A Deficiency

Vitamin A deficiency in the United States is rare, but the disease that results is known as xerophthalmia, which can lead to blindness if untreated. It most commonly occurs in developing nations usually due to malnutrition. Since vitamin A is stored in the liver, it may take up to 2 years for signs of deficiency to appear. Night blindness and very dry, rough skin may indicate a lack of vitamin A. Other signs of possible vitamin A deficiency include decreased resistance to infections, faulty tooth development, and slower bone growth. Vitamin A deficiency is also a known risk factor for severe measles. According to the World Health Organization (WHO), Vitamin A supplementation can significantly reduce mortality rates for children with measles who live in areas with a high prevalence of Vitamin A deficiency. The effectiveness of vitamin A supplementation to treat measles in countries, such as the United States, where vitamin A intakes are generally adequate, is uncertain.

Too much Vitamin A

In the United States, toxic or excess levels of vitamin A are more

of a concern than deficiencies. The Tolerable Upper Intake Level (UL) for adults is 3,000 mcg RAE (Table 2). It would be difficult to reach this level consuming food alone, but some multivitamin supplements contain high doses of vitamin A. Retinol is the form of vitamin A that causes the greatest concern for toxicity. If you take a multivitamin, check the label to be sure the majority of vitamin A provided is in the form of beta-carotene, which appears to be safe. Some medications used to treat acne, psoriasis, and other skin conditions contain compounds that mimic retinol in the body. Much like excessive intake of dietary retinol, these medications have been shown to negatively impact bone health and result in delayed growth in children and teens.

Symptoms of vitamin A toxicity include dry, itchy skin, headache, nausea, and loss of appetite. Signs of severe overuse over a short period of time include dizziness, blurred vision and slowed growth. Vitamin A toxicity can also cause severe birth defects and may increase the risk for bone loss and hip fractures.

Vitamin D

What is Vitamin D?

Vitamin D plays a critical role in the body's use of calcium and phosphorus. It works by increasing the amount of calcium absorbed from the small intestine, helping to form and maintain bones. Vitamin D benefits the body by playing a role in immunity and controlling cell growth and may protect against osteoporosis, high blood pressure, cancer, and other diseases. Children especially need adequate amounts of vitamin D to develop strong bones and healthy teeth.



Food Sources for Vitamin D

The primary food sources of vitamin D are milk and other dairy products fortified with vitamin D. Vitamin D is also found in oily fish (e.g., herring, salmon and sardines) as well as in cod liver oil. In addition to the vitamin D provided by food, we obtain vitamin D through our skin which produces vitamin D in response to sunlight.

How much Vitamin D Do We Need?

The Recommended Dietary Allowance (RDA) for vitamin D appears as micrograms (mcg) of cholecalciferol (vitamin D3) (Table 1). From 12 months to age fifty, the RDA is set at 15 mcg. Twenty mcg of cholecalciferol equals 800 International Units (IU), which is the recommendation for maintenance of healthy bone for adults over fifty. Table 1 lists additional recommendations for various life stages.

Exposure to ultraviolet light is necessary for the body to produce the active form of vitamin D. Ten to fifteen minutes of sunlight without sunscreen on the hands, arms and face, twice a week is sufficient to receive enough vitamin D. This can easily be obtained in the time spent riding a bike to work or taking a short walk with arms and legs exposed. In order to reduce the risk for skin cancer one should apply sunscreen with an SPF of 15 or more, if time in the sun exceeds 10 to 15 minutes.

Vitamin D Deficiency

Symptoms of vitamin D deficiency in growing children include rickets (long, soft bowed legs) and flattening of the back of the skull. Vitamin D deficiency in adults may result in osteomalacia (muscle and bone weakness), and osteoporosis (loss of bone mass). Vitamin D deficiency has been associated with increased risk of common cancers, autoimmune diseases, hypertension, and infectious disease. Research shows that vitamin D insufficiency affects almost 50% of the population worldwide; an estimated 1 billion people. The rising rate of deficiency has been linked to a reduction in outdoor activity and an increase in the use of sunscreen among children and adults. In addition,

those who live in inner cities, wear clothing that covers most of the skin, or live in northern climates where little sun is seen in the winter are also prone to vitamin D deficiency. Since most foods have very low vitamin D levels (unless they are enriched) a deficiency may be more likely to develop without adequate exposure to sunlight. Adding fortified foods to the diet such as milk, and for adults including a supplement, are effective at ensuring adequate vitamin D intake and preventing low vitamin D levels. In the absence of adequate sun exposure, at least 800 to 1,000 IU of vitamin D3 may be needed to reach the circulating level required to maximize vitamin D's benefits.

Who is at Risk —

These populations may require extra vitamin D in the form of supplements or fortified foods:

- **Exclusively breast-fed infants:** Human milk only provides 25 IU of vitamin D per liter. All breast-fed and partially breast-fed infants should be given a vitamin D supplement of 400 IU/day.
- **Dark Skin:** Those with dark pigmented skin synthesize less vitamin D upon exposure to sunlight compared to those with light pigmented skin.
- **Elderly:** This population has a reduced ability to synthesize vitamin D upon exposure to sunlight, and is also more likely to stay indoors and wear sunscreen which blocks vitamin D synthesis.
- **Covered and protected skin:** Those that cover all of their skin with clothing while outside, and those that wear sunscreen with an SPF factor of 8, block most of the synthesis of vitamin D from sunlight.
- **Disease:** Fat malabsorption syndromes, inflammatory bowel disease (IBD), and obesity are all known to result in a decreased ability to absorb and/or use vitamin D in fat stores.

Too much Vitamin D

The Tolerable Upper Intake Level (UL) for vitamin D is set at 100 mcg (4000 IUs) for people 9 years of age and older (Table 2). High doses of vitamin D supplements coupled with



large amounts of fortified foods may cause accumulations in the liver and produce signs of poisoning. Signs of vitamin D toxicity include excess calcium in the blood, slowed mental and physical growth, decreased appetite, nausea and vomiting.

It is especially important that infants and young children do not consume excess amounts of vitamin D regularly, due to their small body size.

Vitamin E: Tocopherol

What is Vitamin E?

Vitamin E benefits the body by acting as an antioxidant, and protecting vitamins A and C, red blood cells, and essential fatty acids from destruction. Research from decades ago suggested that taking antioxidant supplements, vitamin E in particular, might help prevent heart disease and cancer. However, newer findings indicate that people who take antioxidant and vitamin E supplements are not better protected against heart disease and cancer than non-supplement users. Many studies show a link between regularly eating an antioxidant rich diet full of fruits and vegetables, and a lower risk for heart disease, cancer, Alzheimer's Disease, and several other diseases. Essentially, research indicates that to receive the full benefits of antioxidants and phytonutrients in the diet, one should consume these compounds in the form of fruits, vegetables, nuts, and seeds, not as supplements.

Food Sources for Vitamin E

About 60 percent of vitamin E in the diet comes from vegetable oil (soybean, corn, cottonseed, and safflower). This also includes products made with vegetable oil (margarine and salad dressing). Vitamin E sources also include fruits and vegetables,

grains, nuts (almonds and hazelnuts), seeds (sunflower) and fortified cereals.

How much Vitamin E Do We Need?

The Recommended Dietary Allowance (RDA) for vitamin E is based on the most active and usable form called alpha-tocopherol (Table 1). Food and supplement labels list alpha-tocopherol as the unit international units (IU) or micrograms (mcg), not in milligrams (mg). One microgram of alpha-tocopherol equals to 1.5 International units (IU). RDA guidelines state that males and females over the age of 14 should receive 15 mcg (22.5 IUs) of alpha-tocopherol per day. Consuming vitamin E in excess of the RDA does not result in any added benefits.

Vitamin E Deficiency

Vitamin E deficiency is rare. Cases of vitamin E deficiency usually only occur in premature infants and in those unable to absorb fats. Since vegetable oils are good sources of vitamin E, people who excessively reduce their total dietary fat may not get enough vitamin E.

Too much Vitamin E

The Tolerable Upper Intake Level (UL) for vitamin E is shown in Table 2. Vitamin E obtained from food usually does not pose a risk for toxicity. Supplemental vitamin E is not recommended due to lack of evidence supporting any added health benefits. Megadoses of supplemental vitamin E may pose a hazard to people taking blood-thinning medications such as Coumadin (also known as warfarin) and those on statin drugs.

Vitamin K

What is Vitamin K?

Vitamin K is naturally produced by the bacteria in the intestines, and plays an essential role in normal blood clotting, promoting bone health, and helping to produce proteins for blood, bones, and kidneys.

Food Sources for Vitamin K

Good food sources of vitamin K are green, leafy-vegetables such as turnip

Table 1. Recommended Dietary Intake (RDA) and Adequate Intake (AI) for Fat-Soluble Vitamins

Life Stage Group	Vitamin A (mcg ¹ /RAE)	Vitamin D (mcg ²)	Vitamin E (mcg α-TE ³)	Vitamin K (mcg)
Infants⁴				
0 - 6mo	400*	10*	4*	2.0*
6mo - 12mo	500*	10*	5*	2.5*
Children				
1 - 3y	300	15	6	30*
4 - 8y	400	15	7	55*
Males				
9 - 13y	600	15	11	60*
14 - 18y	900	15	15	75*
19 - 30y	900	15	15	120*
31 - 50y	900	15	15	120*
51 - 70y	900	15	15	120*
>70y	900	20	15	120*
Females				
9 - 13y	600	15	11	60*
14 - 18y	700	15	15	75*
19 - 30y	700	15	15	90*
31 - 50y	700	15	15	90*
51 - 70y	700	15	15	90*
>70y	700	20	15	90*
Pregnant				
14 - 18y	750	15	15	75
19 - 30y	770	15	15	90
31 - 50y	770	15	15	90
Lactation				
14 - 18y	1200	15	19	75
19 - 30y	1300	15	19	90
31 - 50y	1300	15	19	90

¹As retinol activity equivalents (RAEs). 1 RAE = 1 mcg retinol or 12 mcg beta-carotene.

²As cholecalciferol (vitamin D3). 10 mcg cholecalciferol = 400 IU of Vitamin D.

³As alpha-tocopherol equivalents. 1 mg of alpha-tocopherol = 1.5 IU of Vitamin E=22IU of d-alpha-tocopherol=33 IU of dl-alpha- tocopherol

⁴At 6 months of age, infants may be introduced to solid foods while remaining on formula or breast milk. There may be some overlap in specific nutrient requirements.

*Indicates an Adequate Intake (AI). All other values are Recommended Dietary Allowance (RDA).

Table 2. Tolerable Upper Intake Levels (UL) for Fat-Soluble Vitamins

Life Stage Group	Vitamin A (mcg/d)	Vitamin D (mcg/d)	Vitamin E (mg a-TE)	Vitamin K*
Infants ¹				
0 - 6mo	600	25	ND ²	ND
6mo - 12mo	600	38	ND	ND
Children				
1 - 3y	600	63	200	ND
4 - 8y	900	75	300	ND
Males/Females				
9 - 13y	1700	100	600	ND
14 - 18y	2800	100	800	ND
19 - 70y	3000	100	1000	ND
>70y	3000	100	1000	ND
Pregnant and Lactating				
<18	2800	100	800	ND
19 - 50y	3000	100	1000	ND

¹At 6 months of age, infants may be introduced to solid foods while remaining on formula or breast milk. There may be some overlap in specific nutrient requirements.

²ND = not determinable due to insufficient data

*An UL for vitamin K was not established.

greens, spinach, cauliflower, cabbage and broccoli, and certain vegetable oils including soybean oil, cottonseed oil, canola oil and olive oil. Animal foods, in general, contain limited amounts of vitamin K.

How Much Vitamin K Do We Need?

To help ensure people receive sufficient amounts of vitamin K, an Adequate Intake (AI) has been established for each age group (Table 1).

Vitamin K Deficiency

Without sufficient amounts of vitamin K, hemorrhaging can occur. Vitamin K deficiency may appear in infants or in people who take anticoagulants, such as Coumadin (warfarin), or antibiotic drugs. Newborn babies lack the intestinal bacteria to produce vitamin K and need a supplement for the first week. Those on anticoagulant drugs (blood thinners) may become vitamin K deficient, but should not change their vitamin K intake without consulting a physician. People taking antibiotics may lack vitamin K temporarily because intestinal bacteria are sometimes killed as a result of long-term use of antibiotics. Also, people



with chronic diarrhea may have problems absorbing sufficient amounts of vitamin K through the intestine and should consult their physician to determine if supplementation is necessary.

Too much Vitamin K

Although no Tolerable Upper Intake Level (UL) has been established for vitamin K, excessive amounts can cause the breakdown of red blood cells and liver damage. People taking blood-thinning drugs or anticoagulants should moderate their intake of foods with vitamin K, because excess vitamin K can alter blood clotting times. Large doses of vitamin K are not advised.

Summary

- Fat-soluble vitamins: A, D, E, and K — are stored in the body for long periods of time, and pose a greater risk for toxicity than water-soluble vitamins. Fat-soluble vitamins are only needed in small amounts.
- Beta carotene is an important antioxidant that the body converts to Vitamin A, and it is found in a variety of fruits and vegetables.
- Inadequate dietary consumption of vitamin D, along with limited sun exposure, makes vitamin D deficiency a growing public health concern.
- Vitamin E benefits the body by acting as an antioxidant, and research indicates that it may offer a protective effect if obtained through a diet rich in fruits and vegetables, as opposed to a supplement or multivitamin.
- The bacteria in our gut produce vitamin K, and it is also found in green leafy vegetables.

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