
Recommended Intakes of Vitamins and Essential Minerals

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Vitamins are substances that, by definition, are essential to life itself, but are not made in the body—or not made in sufficient quantities to support life. Essential minerals are likewise substances required for the day-by-day, minute-to-minute functions of the body. Both must be obtained from foods.

Vitamins and essential minerals were discovered in the course of the long scientific search for understanding about how foods are utilized in the body and which foods or specific substances were necessary to sustain life. As an early step in this direction, researchers isolated and identified the “macronutrients”—fat, protein, and carbohydrate. They learned, however, that experimental animals could not live on diets composed solely of purified fats, proteins and carbohydrates. They also needed some “ash” or minerals, and over a period of time many essential minerals were identified.

In the early 1900s, researchers discovered that there was an unknown fat soluble organic substance that was also essential to life. This was the beginning of the period of vitamin discovery, and the first vitamin was called “fat soluble A.” It was later discovered that there was also an unknown water-soluble substance that was essential to life, and this became known as “water soluble B.” Over a period of about 40 years, it turned out that there were actually many separate B vitamins, and these were identified and named in rapid succession. The numbering system initially developed for some of the B vitamins is still in use (as in B-1, B-2, B-6 and B-12), whereas others are now known by their common names and not by numbers (such as niacin, folic acid and pantothenic acid). Vitamins C, D and E were discovered in due course, as was vitamin K. Some of the missing letters were given to presumed new vitamins that later turned out to be identical to some of the previously named B vitamins. The last of the B vitamins to be identified was folic acid in the 1940s.

Initially the vitamins were known primarily in relation to the deficiency diseases that appeared when diets were severely limited in a particular nutrient. Diets lacking in vitamin A caused night blindness and eventually total blindness. Diets lacking in thiamin or niacin caused beri-beri or pellagra. People deprived of fresh fruits or vegetables for long periods of time, such as sailors on extended voyages of discovery, were afflicted with scurvy due to lack of vitamin C, and entire shiploads of men perished before the

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importance of fresh foods was recognized. Children not exposed to sunlight suffered from rickets due to vitamin D deficiency, unless they obtained an adequate amount from food sources such as fish. Hence the popularity of cod liver oil in the northern countries of Europe. Some essential minerals were also characterized initially by their deficiency diseases. Goiter, for example, is due to iodine deficiency, and the most widespread form of anemia is due to iron deficiency.

These examples illustrate that each individual vitamin has a specific role in metabolism, since deficiencies of different vitamins result in separate and identifiable deficiency syndromes. The same is true of the essential minerals—each has a specific role that cannot be filled by other minerals. Today, of course, many of the specific metabolic roles of these nutrients have been identified. This chapter provides concise descriptions of the metabolic roles, deficiency symptoms, Recommended Dietary Allowances (RDAs), and Tolerable Upper Intake Level (UL) for all the vitamins and essential minerals, based on the most current findings of the Food and Nutrition Board of the Institute of Medicine.

As a group, the new dietary recommendations of the Food and Nutrition Board are called Dietary Reference Intakes (DRIs). Not only are the new DRIs more complicated than the old RDAs, the system for establishing the DRIs is also more complex. A number of different expert committees have been convened to establish recommendations for related nutrients, and each set of recommendations is being published as a separate book. The references listed at the end of this chapter provide citations for all of the DRI publications on vitamins and minerals. (The reports on macronutrients and electrolytes have not yet been published.) The DRIs may include various different measures of adequacy or safety, as listed below.

- EAR, Estimated Average Requirement. This is the median usual intake value that is estimated to meet the *requirement* of *half* the healthy individuals in a life stage and gender group. By definition, the needs of half the group would not be met.
- RDA, Recommended Dietary Allowance. This is the average daily dietary intake level that is sufficient to meet the nutrient requirement of *nearly all healthy individuals* in a particular life stage and gender group. By definition, the RDA is two standard deviations above the EAR. According to the Food and Nutrition Board, “**the RDA is intended for use primarily as a goal for usual intake of individuals.**”
- AI, Adequate Intake. If there is not enough evidence to establish an EAR, then by definition no RDA can be established (since the RDA is 2 standard deviations above the EAR). In these cases, an AI is established instead of an RDA. The AI represents the observed or calculated mean intake level in apparently healthy people.
- UL, Upper Level of Tolerable Intake. This is the highest level of continuing daily nutrient intake that is likely to pose *no risk* of adverse health effects in almost all individuals in the specified life stage group. By definition, the UL is a *safe* level of intake for the specified group.

For individuals who wish to evaluate the adequacy of their own diets, the bottom line is that the RDA continues to provide the accepted target for nutrient intake. If there is no RDA, the AI can serve a similar purpose. Adequate intake for the individual is best assured if the intake level for a given nutrient is at or somewhat above the RDA or the AI, rather than below these targets.

Following the groupings used by the Food and Nutrition Board, the vitamins and minerals covered are those shown below. The Food and Nutrition Board reports for each of these are cited in the reference list at the end of this chapter.

Bone-related nutrients

- Calcium
- Phosphorus
- Magnesium
- Vitamin D
- Fluoride

The B vitamins:

- Thiamin
- Riboflavin
- Niacin
- Vitamin B-6
- Folate (folic acid)
- Vitamin B-12
- Pantothenic acid
- Biotin
- Choline

The antioxidants:

- Vitamin C
- Vitamin E
- Selenium
- Beta-carotene

Additional vitamins and trace minerals:

- Vitamin A
- Vitamin K
- Chromium
- Copper
- Iodine
- Iron
- Manganese
- Molybdenum
- Zinc
- Boron
- Nickel
- Vanadium

Bone-Related Nutrients (FNB 1997)

Calcium

ROLE: Calcium is necessary for nerve transmission, muscle contraction, glandular secretion, and the contraction and dilation of the blood vessels. These needs are met by that fraction of body calcium (less than one percent) found in the blood, muscle, and other tissues. Over 99 percent of body calcium is in the bones and teeth, where hydroxyapatite makes up about 40 percent of the weight of bone. Bone is not a static tissue, but is dynamic, undergoing constant breakdown and rebuilding (remodeling). In growing children, the rate of building exceeds the rate of breakdown, but in aging adults the rate of building lags behind the rate of breakdown. The skeleton serves as a reservoir for calcium when the mineral is needed for other purposes.

DEFICIENCY: Chronic calcium deficiency contributes to a reduction in bone mass and the development of osteoporosis. It has been estimated that 21 percent of White and Asian Americans have osteoporosis, together with about 16 percent of Hispanics and 10 percent of African-American women. In addition, almost 40 percent of American women 50 years of age or older have low bone density (but not so low as to qualify as osteoporotic). In the United States, there are about 1.5 million bone fractures per year due to osteoporosis.

RDA: There is not sufficient information to establish an Estimated Average Requirement or an RDA for calcium. The Adequate Intake levels are:

- 500 mg per day for children 1-3
- 800 mg per day for children 4-8
- 1300 mg per day for children and teens 9-18
- 1000 mg per day for adults 19-50
- 1200 mg per day for adults over 50

UL: A tolerable upper intake level of 2500 mg per day is established for calcium, for adults, based on the potential for hypercalcemia (milk alkali syndrome) from excess calcium intake.

Phosphorus

ROLE: Phosphorus is a component of membrane phospholipids, nucleotides and nucleic acids, and a component of bones and teeth. It functions to buffer body fluids to maintain a normal pH, to temporarily store and transfer energy derived from metabolic fuels, and to activate many catalytic proteins through phosphorylation.

DEFICIENCY: Phosphorus is so widely distributed in foods that deficiency is produced only in near starvation or in refeeding of depleted individuals without adequate attention to supplying phosphorus.

RDA: The RDA for phosphorus is 700 mg for adults, 1250 mg for children and teens ages 9-18, and around 500 mg for younger children.

UL: The Tolerable Upper Intake Level for phosphorus is set at 4 grams per day (4000 mg), for adults, based on the intake levels associated with maximum normal adult serum values of serum inorganic phosphorus, although “no reports exist of untoward effects following high dietary phosphorus intakes in humans.”

Magnesium

ROLE: Magnesium is a required cofactor for more than 300 enzyme systems and is required for energy production in the body. It is necessary for maintaining appropriate intracellular levels of potassium, sodium, and calcium. Fifty to sixty percent of body magnesium is found in the skeleton.

DEFICIENCY: Severe magnesium depletion results in low levels of blood calcium and may result in hyperexcitability of nerves and muscles. Magnesium depletion is also associated with cardiac complications including arrhythmias. Magnesium deficiency may increase the risk of osteoporosis.

RDA: The RDA for magnesium is about 320 mg for adult women and about 420 mg for adult men.

UL: “Magnesium, when ingested as a naturally occurring substance in foods, has not been demonstrated to exert any adverse effects,” so no UL is established for magnesium consumed in conventional foods. A Tolerable Upper Intake Level for magnesium from pharmaceutical products (such as laxatives) or from dietary supplements is set at 350 mg per day, for adults, based on the recognized laxative effect (diarrhea). The osmotic diarrhea induced by magnesium salts is described as mild and reversible.

Vitamin D

ROLE: Vitamin D maintains serum calcium and phosphorus at supersaturating levels that are deposited in bone as calcium hydroxyapatite. High serum levels are maintained by increasing intestinal absorption of calcium and phosphorus and by mobilizing calcium from bone if needed.

DEFICIENCY: Vitamin D deficiency results in inadequate mineralization or demineralization of bone. In children, this condition leads to rickets. In adults, it leads to osteomalacia. Deficiency can result from inadequate production of vitamin D (normally produced from a cholesterol precursor in the skin, during sun exposure) or from inadequate conversion of vitamin D to its active form in the body.

RDA: There is insufficient information to establish an Estimated Average Requirement or a Recommended Dietary Allowance for vitamin D. An Adequate Intake

level (AI) is established at 5 µg per day (200 IU) for all persons through age 50, 10 µg per day (400 IU) for persons 51 to 70, and 15 µg per day (600 IU) for persons over 70.

UL: Excess vitamin D can cause hypercalcemia (high blood levels of calcium). An Upper Tolerable Intake Level for vitamin D for adults is established at 50 µg per day (2000 IU).

Fluoride

ROLE: Fluoride has a high affinity for calcium and has the ability to stimulate formation of calcified tissues (bones and teeth). Fluoride helps protect against dental caries.

DEFICIENCY: Dental caries was shown to be higher in communities without fluoridated water supplies, prior to the wide availability of fluoridated dental products.

RDA: There is inadequate information to establish an Estimated Average Requirement or a Recommended Dietary Allowance for fluoride. An Adequate Intake level (AI) is established at 3 mg per day for adult women and 4 mg per day for adult men. The AI is 3 mg for teens 14-18, 2 mg for children 9-13, 1 mg for children 4-8, and less than one mg for children under 4.

UL: Excess exposure to fluoride in water can result in mottled tooth enamel (fluorosis). Based on this effect, a tolerable upper intake level for fluoride is established at 10 mg per day for adults and for children over the age of 8. For younger children, the UL is 2.2 mg for children 4-8, 1.3 mg for children 1-3, and less than one mg for infants.

The B Vitamins (FNB 1998)

Thiamin (Vitamin B-1)

ROLE: Coenzyme involved in metabolism of carbohydrates and branched-chain amino acids. Coenzyme form is thiamin pyrophosphate (TPP).

DEFICIENCY: Classical deficiency known as beriberi. Modern deficiency mainly associated with alcoholism. Clinical signs of deficiency include anorexia and weight loss, apathy and confusion, irritability, muscle weakness and cardiovascular effects.

RDA: 1.2 mg per day for men, 1.1 mg per day for women

UL: None established. "There are no reports available of adverse effects from consumption of excess thiamin by ingestion of food and supplements."

Riboflavin (Vitamin B-2)

ROLE: Coenzyme in oxidation/reduction reactions, including those involved in energy production. Coenzyme forms are flavin mononucleotide (FMN) and flavin-adenine dinucleotide (FAD).

DEFICIENCY: Cracks and sores around the mouth and nose, sore throat, magenta tongue, skin rash.

RDA: 1.3 mg per day for men, 1.1 mg per day for women

UL: None established. “No adverse effects associated with riboflavin consumption from food or supplements have been reported.”

Niacin

ROLE: Coenzyme for oxidation/reduction reactions. Coenzyme form is nicotinamide adenine dinucleotide (NAD) or its phosphate form (NADP). Plays a key role in energy production and in synthesis of fatty acids and steroids. Also involved in DNA replication and repair and in cell differentiation.

DEFICIENCY: Classic deficiency disease is pellagra. Symptoms include skin rash, vomiting, constipation or diarrhea, bright red tongue, depression, apathy, headache, fatigue, loss of memory. In industrialized countries, deficiency now seen only in chronic alcoholism and rare metabolic disorders.

RDA: 16 mg per day for men, 14 mg per day for women

UL: 35 mg per day, based on flushing reaction. “The term flushing covers a burning, tingling, and itching sensation as well as a reddened flush primarily on the face, arms and chest.” It is due to dilation of the blood vessels. Much higher levels of niacin are sometimes given as therapy for high cholesterol, but this is considered a medical use. Liver toxicity has been observed at very high levels of intake of nicotinic acid and of niacinamide (typically from doses in the range of 3 to 9 grams per day, taken over a period of months or years for the treatment of elevated cholesterol levels).

Vitamin B-6 (Pyridoxine)

ROLE: Coenzyme in the metabolism of amino acids and in energy production. Major coenzyme forms in humans are pyridoxal phosphate (PLP) and pyridoxamine phosphate (PMP).

DEFICIENCY: Clinical effects of deficiency are dermatitis, anemia, convulsions, depression, and confusion.

DISEASE PREVENTION: Involved in one-carbon cycle, which produces methyl groups to be used in synthesis of other compounds. Inadequate levels of B-6 can lead to accumulation of homocysteine, which may be a risk factor for heart disease. Adequate B-6 facilitates conversion of homocysteine to cysteine.

RDA:
1.3 mg per day for men and women 19-50
1.5 mg per day for women over 50
1.7 mg per day for men over 50

UL: “No adverse effects have been associated with high intake of vitamin B-6 from food sources.” Large supplemental doses of B-6 have been used to treat conditions such as carpal tunnel syndrome and premenstrual syndrome, and have been associated with the development of sensory neuropathy. For supplemental uses, the Tolerable Upper Intake Level (UL) is 100 mg per day for adults.

Folate (Folic Acid)

ROLE: Folate is a coenzyme in the single-carbon cycle. It is essential for DNA synthesis and normal cell division and for interconversions of amino acids, including the conversion of homocysteine to methionine. Folate is the complex form of this nutrient that occurs naturally in foods. Folic acid is the synthetic form used in fortified foods and dietary supplements. Folic acid is more stable and more completely absorbed than folate from foods.

DEFICIENCY: Inadequate folate intake leads to a megaloblastic type of anemia. In advanced stages, the anemia typically results in symptoms of weakness, fatigue, difficulty concentrating, irritability, headache, palpitations, and shortness of breath.

PREVENTION OF NEURAL TUBE BIRTH DEFECTS: 400 µg of folic acid daily from fortified foods and/or supplements is recommended for women capable of becoming pregnant, in addition to their dietary folate intake, in order to reduce the risk of neural tube birth defects.

PREVENTION OF CARDIOVASCULAR DISEASE: While there is considerable evidence suggesting that folic acid may reduce the risk of heart disease and stroke by reducing levels of homocysteine, the Food and Nutrition Board believes more evidence is needed before basing a dietary recommendation on these cardiovascular effects.

RDA: 400 µg per day for adults, as dietary folate equivalents (DFE). One microgram of folate from food is equal to 0.5 µg of synthetic folic acid. In addition to consuming folate from food, it is recommended that women capable of becoming pregnant take 400 µg of folic acid daily from fortified foods and/or supplements, to reduce the risk of neural tube birth defects.

UL: An Upper Tolerable Intake Level (UL) of 1000 µg is established for folic acid from fortified foods or dietary supplements, based on the potential for folic

acid to mask symptoms of vitamin B-12 deficiency and thus precipitate or exacerbate neuropathy in people who are B-12 deficient.

Vitamin B-12

ROLE: Vitamin B-12 (cobalamin) is a coenzyme in the one-carbon cycle that generates methyl groups to be used in the synthesis of other compounds. In that cycle, B-12 is needed for the reaction that converts homocysteine back to methionine. Vitamin B-12 is essential for normal blood formation and neurological function.

DEFICIENCY: Vitamin B-12 deficiency is known as “pernicious anemia.” It causes a megaloblastic anemia identical to that caused by folate deficiency. Symptoms include pallor of the skin, diminished energy, fatigue, shortness of breath, and palpitations. Vitamin B-12 deficiency may also cause neurological disorders including tingling and numbness in the hands and feet, abnormalities of gait, loss of concentration, memory loss, disorientation, mood changes, dementia, visual disturbances, insomnia, impotency, and impaired bowel and bladder control. Gastrointestinal symptoms may include sore tongue, appetite loss, flatulence, and constipation.

RDA: The Recommended Dietary Allowance is 2.4 µg per day for adults. However, because many people over the age of 50 have low stomach acid and therefore may not absorb dietary B-12 very well, the Food and Nutrition Board recommends that people over 50 should get most of their B-12 from foods fortified with B-12 or from nutritional supplements containing B-12. The synthetic form of B-12 used in these products is more easily absorbed than the naturally-occurring B-12 in foods.

UL: None established. “No adverse effects have been associated with excess B-12 intake from food or supplements in healthy individuals.”

Pantothenic Acid

ROLE: Pantothenic acid is a component of coenzyme A and thus is involved in many metabolic processes, including energy production, fatty acid metabolism, and the synthesis of many compounds including amino acids, steroid hormones, and neurotransmitters.

DEFICIENCY: Pantothenic acid is widely distributed in foods, and deficiency has never been reported except as a result of feeding an antagonist or semisynthetic diets virtually devoid of pantothenic acid for experimental or medical purposes.

RDA: An Adequate Intake (AI) level of 5 mg per day is established for adults. There is not sufficient information to establish an RDA.

UL: None established. “No reports of adverse effects of oral pantothenic acid in humans or animals were found.”

Biotin

ROLE: Biotin is a coenzyme in carboxylation reactions, including those involved in energy production and the metabolism of fatty acids.

DEFICIENCY: Raw egg whites contain a biotin antagonist, and biotin deficiency has been observed primarily in people consuming raw egg white over long periods of time or receiving total parenteral nutrition without biotin. Symptoms include skin rash, hair loss, depression, lethargy, and hallucinations.

RDA: An Adequate Intake (AI) for biotin is 30 µg per day for adults. The data are not adequate to permit establishment of an Estimated Average Requirement or a Recommended Dietary Allowance.

UL: None established. “No reported adverse effects of biotin in humans or animals were found.”

Choline

ROLE: Choline is an important nutrient but has not been considered a vitamin, since there is some biosynthesis of choline in the body. For the first time, the Food and Nutrition Board established an intake recommendation for choline in 1998, recognizing that the amount of choline synthesized in the body may not be adequate to meet nutrient needs. Choline is a precursor for the neurotransmitter acetylcholine. It is also important for the structural integrity of membranes and for the metabolism of lipids and cholesterol.

DEFICIENCY: Fatty liver and damage to the liver can occur when people or animals are deprived of adequate choline.

DISEASE PREVENTION: Some research suggests that choline may improve memory or prevent dementia, but more study is needed. Choline might have a role in decreasing the risk of cardiovascular disease by modestly reducing cholesterol levels or by decreasing homocysteine levels, but more research is needed.

RDA: The Adequate Intake (AI) for choline is 425 mg per day for women and 550 mg per day for men. There are not sufficient data to permit the establishment of an Estimated Average Requirement or a Recommended Dietary Allowance.

UL: An Upper Tolerable Intake Level of 3.5 grams per day is established for choline, for adults. “Choline doses that are orders of magnitude greater than estimated intake from food have been associated with body odor, sweating, salivation, hypotension [low blood pressure], and hepatotoxicity in humans.”

The Antioxidants (FNB 2000)

Vitamin C

ROLE: Vitamin C functions as a water-soluble antioxidant, and it is also a cofactor for enzymes involved in the biosynthesis of collagen, carnitine, and neurotransmitters. Vitamin C is an effective antioxidant that readily scavenges reactive oxygen species (ROS) and reactive nitrogen species (RNS). Vitamin C is present in the tissues at relatively high levels and thus provides substantial antioxidant protection in the eye, in white blood cells, and in semen. It also helps protect LDL cholesterol against oxidation. Vitamin C also serves to regenerate other biological antioxidants such as glutathione and vitamin E, to restore them to their active state. Vitamin C also modulates the absorption, transport and storage of iron.

DEFICIENCY: Scurvy is the classic vitamin C deficiency disease, and its symptoms are related to defects in connective tissue. Symptoms of deficiency include fatigue, weakness, inflammation and bleeding of the gums and other tissues, and impaired wound healing. "Scurvy is rare in developed countries but is occasionally seen in individuals who consume few fruits and vegetables, peculiar or restricted diets, or in those who abuse alcohol or drugs."

RDA: The RDA for vitamin C is 75 mg per day for women and 90 mg per day for men, for nonsmokers. Because smoking increases oxidative stress, the RDA for vitamin C in smokers is increased to 110 mg per day for women and 125 mg per day for men.

UL: An Upper Tolerable Intake Level of 2 grams per day is established for vitamin C, for adults, due to the potential for osmotic diarrhea and gastrointestinal disturbances at higher levels.

Vitamin E

ROLE: Vitamin E is a chain-breaking antioxidant. It protects lipids against peroxidation.

DEFICIENCY: Vitamin E deficiency is very rare and is seen only in people with metabolic abnormalities that prevent absorption of the vitamin. When deficiency occurs, the primary symptom is peripheral neuropathy.

RDA: The RDA for vitamin E is 15 mg for both men and women. The recommendation is based only on alpha-tocopherol, and other forms of tocopherol that occur naturally in food are not considered to contribute to vitamin E activity.

DISEASE PREVENTION: "A large and growing body of experimental evidence suggests that high intakes of vitamin E may lower the risk of some chronic diseases, especially heart disease. However, the limited and discordant clinical trial evidence

available precludes recommendations at this time of higher vitamin E intakes to reduce chronic disease risk.”

UL: The Tolerable Upper Intake Level for adults is set at 1000 mg per day of *supplemental* vitamin E. The UL is based on animal evidence for an increased risk of hemorrhage at extremely high levels of intake. The human evidence for a potential hemorrhagic effect was found to be “preliminary and provocative, but not convincing” and was not used as the basis for the UL. In human clinical trials, one study using 50 mg of vitamin E reportedly found an increase in hemorrhagic stroke, but other large-scale trials using much higher levels of vitamin E found no such effect.

Selenium

ROLE: Selenium is required as a component of the enzyme glutathione peroxidase, which protects against oxidative stress. Other selenium-containing enzymes are involved in the regulation of thyroid hormone action and the regeneration of vitamin C from its oxidized forms.

DEFICIENCY: Selenium deficiency in animals can result in lipid peroxidation and cardiac injury if it occurs together with vitamin E deficiency. A cardiomyopathy known as Keshan disease has been associated with selenium deficiency in China.

RDA: The RDA for selenium is 55 µg per day for both men and women.

UL: The Tolerable Upper Intake Level is set at 400 µg per day for adults, based on the potential for toxicity at levels above 800 µg per day. Reported symptoms of toxicity have included hair and nail brittleness and loss, gastrointestinal disturbances, skin rash, garlic breath odor, fatigue, irritability, and nervous system abnormalities.

Beta-Carotene and Other Carotenoids

Generous intakes of beta-carotene and other carotenoids from foods are associated with lower risk of several chronic diseases. “This evidence, although consistent, cannot be used to establish a requirement for beta-carotene or carotenoid intake” because the effects could be due to other components of the food or to other behaviors adopted by people who eat a lot of fruits and vegetables. One clearly recognized nutritional function of certain carotenoids is to serve as precursors of vitamin A. The provitamin carotenoids include alpha-carotene, beta-carotene, and beta-cryptoxanthin. No EAR, RDA, or AI is established for any of the carotenoids, except to the extent that they provide vitamin A activity. See the vitamin A findings, below. No UL is established for carotenoids from foods. The report concludes that “beta-carotene supplements are not advisable, other than as a provitamin A source and for the prevention and control of vitamin A deficiency in at-risk populations.”

Additional Vitamins and Trace Minerals (FNB 2001)

Vitamin A

ROLE: Vitamin A is important for normal vision, integrity of the epithelial cells (the skin and the cells lining the inner surfaces of the body), gene expression, reproduction, embryonic development, growth and immune function.

DEFICIENCY DISEASE: Night blindness is an early symptom of vitamin A deficiency, and it responds rapidly to treatment with vitamin A. In its severe form, vitamin A deficiency can lead to permanent blindness, and it is estimated that 250,000 to 500,000 children under the age of five go blind every year in the developing world because of severe vitamin A deficiency. Vitamin A supplementation programs in these parts of the world have been sponsored for decades by international organizations. The supplementation has been shown not only to help protect eyesight but also to reduce rates of illness and death in the children treated.

RDA: Vitamin A can be obtained from animal sources as retinol or from plant sources as carotenoids, especially beta-carotene. The RDA for vitamin A is 700 µg of retinol activity equivalents (RAE) per day for women and 900 µg per day for men. These amounts are equivalent to 2100 International Units (IU) for women and 2700 IU for men, when the vitamin A is provided by retinol.

UL, ADULTS: Massive amounts of vitamin A can cause birth defects in animals, and excess vitamin A is believed to be teratogenic in humans as well. An Upper Tolerable Intake Level (UL) of 3000 µg of retinol per day is established for adults. This is equivalent to 10,000 IU. This upper limit applies only to vitamin A as retinol, and there is no upper limit established for intakes of provitamin A in the form of carotenoids, including beta-carotene.

UL, CHILDREN: The upper limits for children are extrapolated from those established for adults. The upper limits are stated in micrograms of retinol. To convert to International Units (IU), multiply by three. The ULs for vitamin A for children are:

- 600 µg per day for children under the age of 4 (1800 IU)
- 900 µg per day for children 4-8 (2700 IU)
- 1700 µg per day for children 9-13 (5100 IU)
- 2800 µg per day for teens 14-18 (8400 IU)

Vitamin K

ROLE: Vitamin K is a coenzyme involved in the synthesis of the active forms of certain proteins involved in blood coagulation and bone metabolism.

DEFICIENCY: Deficiency of vitamin K results in slow blood clotting and, in severe cases, bleeding.

RDA: An Adequate Intake (AI) is established of 120 µg per day for men and 90 µg per day for women. Data are insufficient to permit establishment of an Estimated Average Requirement and a Recommended Dietary Allowance.

UL: None established. “No adverse effects associated with vitamin K consumption from food or supplements have been reported in humans or animals.”

Chromium

ROLE: Chromium potentiates the action of insulin and thus plays a role in glucose tolerance.

DEFICIENCY: Chromium deficiency has been reported in patients who received total parenteral nutrition without added chromium for an extended period of time. Glucose utilization was impaired and insulin requirements were raised.

RDA: An Adequate Intake (AI) is established for chromium of 35 µg per day for men and 25 µg per day for women. Data are inadequate for establishment of an Estimated Average Requirement or a Recommended Dietary Allowance.

UL: No UL is established for chromium. “No adverse effects have been convincingly associated with excess intake of chromium from food or supplements, but this does not mean that there is no potential for adverse effects resulting from high intakes.”

Copper

ROLE: Copper is a component of a number of enzymes that are involved in reducing molecular oxygen. Copper is part of numerous enzymes involved in metabolizing substances such as histamine, serotonin, epinephrine, norepinephrine, and dopamine. Copper is a component of enzymes that oxidize ferrous iron and facilitate the binding of iron to transferrin, and is also part of cytochrome c oxidase, a critical component of energy production.

DEFICIENCY: Copper deficiency is rare but results in a hypochromic anemia. Deficiency may also reduce bone density.

RDA: The RDA for copper is 900 µg per day for adults.

UL: The Tolerable Upper Intake Level for adults is 10,000 µg per day of copper (10 mg per day), for adults, based on the potential for excessive copper intake to cause liver damage.

Iodine

ROLE: Iodine is an essential component of the thyroid hormones.

DEFICIENCY: Deficiencies of iodine result in inadequate thyroid hormone activity, leading to mental retardation, goiter, cretinism, and other growth and developmental abnormalities. Goiter is due to enlargement of the thyroid and is usually the earliest clinical sign of iodine deficiency.

RDA: The RDA for iodine is 150 µg per day for adults.

UL: The Tolerable Upper Intake Level for iodine is 1.1 mg (1100 µg) per day, for adults.

Iron

ROLE: Iron is a component of hemoglobin, which transports oxygen to body tissues. Iron is also a component of numerous other proteins and enzymes.

DEFICIENCY: Iron deficiency results in anemia, developmental delays, cognitive impairment, adverse pregnancy outcomes, and impaired physical work performance.

RDA: The RDA for iron is 18 mg per day for women of childbearing age and 8 mg per day for men and for postmenopausal women. The RDA for iron in pregnancy is 27 mg per day.

UL: The Tolerable Upper Intake Level is 45 mg per day, for adults, based on the potential for gastrointestinal distress.

Manganese

ROLE: Manganese is an essential component of numerous enzymes involved in bone formation and in the metabolism of amino acids, lipids, and carbohydrates.

DEFICIENCY: Manganese deficiency has been reported in animals but rarely in humans.

RDA: An Adequate Intake (AI) for manganese is established at 2.3 mg per day for men and 1.8 mg per day for women. Data are inadequate for establishment of an Estimated Average Requirement and a Recommended Dietary Allowance.

UL: A Tolerable Upper Intake Level of 11 mg per day is established for adults, based on the fact that this is the likely upper limit of manganese in Western diets and there have been no observed adverse effects at this level. Adverse effects were observed in one study at a level of 15 mg of manganese per day.

Molybdenum

ROLE: Molybdenum is an essential cofactor for some enzymes including sulfite oxidase.

DEFICIENCY: No deficiency has been produced in animals or in humans as a result of dietary restriction of molybdenum.

RDA: The RDA for molybdenum is 45 µg per day for adults.

UL: The Tolerable Upper Intake Level for molybdenum is 2 mg (2000 µg) per day, based on evidence of impaired reproduction and growth in animals consuming high levels of molybdenum.

Zinc

ROLE: Zinc is an essential component of nearly 100 enzymes.

DEFICIENCY: Zinc deficiency in children can result in impaired growth, and zinc deficiency is also associated with poor pregnancy outcome and reduced immune function.

RDA: The RDA for zinc is 8 mg per day for women and 11 mg per day for men.

UL: The Tolerable Upper Intake Level for zinc is 40 mg per day, based on evidence that high intakes of zinc can impair copper status.

Boron, Nickel and Vanadium

ROLE: While some studies have suggested possible functional roles for these nutrients, there is not general agreement that they are necessary in human nutrition.

RDA: No Adequate Intake level, Estimated Average Requirement, or Recommended Dietary Allowances were established for boron, nickel, or vanadium.

UL: The Tolerable Upper Intake Level for adults is 20 mg per day for boron, 1 mg per day for nickel, and 1.8 mg per day for vanadium.

References:

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