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Dietary Reference Intakes: Vitamins

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Introduction

The Dietary Reference Intakes (DRIs) were developed by committees of American and Canadian scientists under the auspices of the Food and Nutrition Board of the National Academies' Institute of Medicine. The DRIs include recommended intakes for nutrients (Recommended Dietary Allowances (RDAs) or Adequate Intakes (AIs)), and are intended to replace the former Recommended Nutrient Intakes (RNIs) in Canada and the former Recommended Dietary Allowances in the United States. For many nutrients, a Tolerable Upper Intake Level (UL) has also been established, and reflects a level that customary intakes should not exceed. To date DRIs have been released for vitamins, minerals, macronutrients and energy[1-5]. This issue addresses the DRIs for vitamins. The previous issue of the Whitehall-Robins Report (January 2003) provided a more complete explanation of the DRIs and also addressed DRIs for minerals[6].

Focus on Vitamin A, Vitamin D, Vitamin E, Vitamin C, Folate, Vitamin B_6 and Vitamin B_{12}

***Vitamin A and carotenoids*[3,4]:** The units for vitamin A currently used on food and supplement labels and in nutrient databases include Retinol Equivalents (RE) and International Units (IU). 1 RE = 1 µg retinol or 6 µg beta-carotene, while using IU, 1 RE = 3.33 IU retinol or 10 IU beta-carotene. In the DRI report, new units for vitamin A (Retinol Activity Equivalents, RAE) were proposed. These units reflect recent knowledge that conversion to retinol of *food* carotenoids (but not beta-carotene in supplements) is only about half as efficient as was previously believed. Thus, the new conversion factors for foods are 12 µg beta-carotene/µg retinol (instead of 6 µg) and 20 IU beta-carotene/µg retinol (instead of 10 IU). Until food composition tables and labels are updated, plant sources of vitamin A expressed in RE or IU need to be divided by 2 to obtain the value in RAE. For example, a serving of mango containing 650 µg RE would provide 325 µg RAE. The changes in units do not affect retinol; thus, 1 RAE still equals 1µg retinol and 3.33 IU retinol. For example, the RDA for adult women is 700 µg RAE, which equals 700 µg retinol or 2331 IU retinol. The UL applies only to preformed retinol, and was based on risk of teratogenicity in women of childbearing age, and risk of liver abnormalities in other age/sex groups. There were not enough data to set a UL for carotenoids; however, because beta-carotene supplements in very high doses don't appear to prevent chronic disease and may be harmful to certain subgroups such as heavy smokers, their use is currently recommended only as a provitamin A source.

***Vitamin D*[1]:** In recent years, there has been increased recognition of the importance of vitamin D in preventing aging bone loss. Accordingly, the new recommendations are higher than in the past, particularly for older adults. Although sunlight can also contribute to vitamin D production, it is not a reliable source for Canadians. During the winter the intensity of ultraviolet light is insufficient to lead to endogenous synthesis, and endogenous synthesis is blocked by sunscreen use. In a recent study, large proportions of older Canadians, with vitamin D intakes below the current AI, were found to have low serum vitamin D levels[7].

***Vitamin E*[4]:** In the past, vitamin E content of foods was expressed in α-tocopherol equivalents (α-TE), which reflected biological activity for other tocopherols and tocotrienols in addition to α-tocopherol. It is now recognized that only α-tocopherol, and more specifically, its 2R-stereoisomers, is maintained in plasma. Accordingly, for purposes of meeting the requirement, only the naturally-occurring form (RRR-) and the other three synthetic 2R α-tocopherol stereoisomers (RSS, RSR, RRS) are biologically active, and the RDA is expressed in mg of α-tocopherol. Until food tables are revised to reflect the new units, vitamin E content of foods expressed in α-TE can be multiplied by 0.8 to approximate the content in mg α-tocopherol. For example, a diet providing 17 mg α-TE would contain 17 x 0.8 = 13.6 mg α-tocopherol. Vitamin E supplements frequently list the vitamin E content in International Units (IU). If the supplement indicates that it contains *d*-α-tocopherol ('natural source', or RRR), multiplying the content in IU by 0.67 yields mg α-tocopherol. For example, 50 IU *d*-α-tocopherol = 50 x 0.67 = 33 mg α-tocopherol. If the supplement contains *dl*-α-tocopherol (a synthetic form containing both 2R and 2S stereoisomers), multiplying the content in IU by 0.45 yields mg α-tocopherol. Thus a supplement with 50 IU *dl*-α-tocopherol would provide 50 x 0.45 = 22.5 mg α-tocopherol. The UL of 1000 mg α-tocopherol for vitamin E applies to any form of supplemental vitamin E, and is based on an increased tendency to hemorrhage.

***Vitamin C*[3]:** Increased recommendations (e.g., 90 mg/d for adult men vs the 1990 RNI of 40 mg) reflect vitamin C's role in providing antioxidant protection. Because smoking increases antioxidant stress, to attain the same level of antioxidant protection smokers need 35 mg/d more than non-smokers. The UL for vitamin C is based on risk of diarrhea and gastrointestinal disturbances at high intakes.

***Folate*[2]:** Folic acid, the form of folate used in supplements or fortified foods is in the monoglutamate form, which is the form that is absorbed. Folate in food is present in the polyglutamate form, with 1-6 additional glutamate residues that must be cleaved before folate can be absorbed in the monoglutamate form. Because this cleavage is incomplete, food folates aren't as well absorbed as folic acid, and new units proposed in the DRI report account for this difference. One dietary folate equivalent (DFE) = 1 µg food folate, 0.6 µg synthetic folate consumed with food, or 0.5 µg synthetic folate taken on an empty stomach. Thus a supplement with 400 µg folic acid, taken with water on an empty stomach, would provide 400/0.5 = 800 µg DFE, while a slice of bread fortified with 20 µg folic acid would provide 20/0.6 = 33 µg DFE. To prevent the risk of neural tube defects, it is recommended that women capable of becoming pregnant obtain 400 µg folic acid per day (from fortified foods and/or a supplement) in addition to food folate from a varied diet. The UL applies only to folic acid from supplements or fortified foods, and is based on the risk that high intakes could mask vitamin B_{12} deficiency.

***Vitamin* B_6[2]:** Vitamin B_6 needs of older adults are higher than those of young adults. For example, compared to young adults, older adults appear to need more B_6 to maintain low plasma homocysteine levels. The UL for vitamin B_6 is based on the risk of sensory neuropathy, which has been observed in individuals taking large amounts of pyridoxine as a supplement.

***Vitamin* B_{12}[2]:** About 10-30% of adults over age 50 have low gastric acid levels. Acid is needed to remove B_{12} from protein that it's bound to in food, so that it can bind to Intrinsic Factor and be absorbed. Thus, older adults with low gastric acid levels may malabsorb food sources of B_{12}. To prevent this, adults over 50 are recommended

to obtain the majority of their B_{12} from a supplement or fortified foods, as synthetic B_{12} is not bound to protein and can bind to Intrinsic Factor even when gastric acid levels are low.

Summary and Conclusions

Several important changes have occurred in regard to recommended intakes of vitamins. Compared to previous recommendations, recommended intakes of several vitamins have increased; improved knowledge about biological activity has led to new units for vitamin A, vitamin E and folate; and there are specific recommendations for older adults for vitamin D, vitamin B_6 and vitamin B_{12}. Upper Levels have been established for many vitamins, and in some cases apply only to intakes from supplements and fortified foods, or only to a specific form of the vitamin (e.g., preformed retinol for vitamin A).

Table 1. Recommended Intakes and Upper Levels of Vitamins for Adults (≥19 yrs of age)

Vitamin	RDA/AI* Male	RDA/AI* Female	Upper Level	Food Sources[1]
Vitamin A (µg RAE)[2]	900	700	3000[3]	Retinol: organ meats, dairy products Carotenoids: deep green/yellow vegetables, mango, papaya
Vitamin D (µg)[4]	5* (≤50) 10* (51-70) 15* (>70)	5* (≤50) 10* (51-70) 15* (>70)	50	Fluid milk, margarine, fatty fish and fish oils
Vitamin E (mg α-tocopherol)[5]	15	15	1000[6]	Vegetable oils, almonds, sunflower seeds, peanut butter
Vitamin K (µg)	120*	90*	ND[7]	Leafy greens, certain vegetable oils (e.g., soy, canola, but not corn, sunflower or safflower)
Vitamin C (mg)	90	75	2000	Fruits and vegetables (e.g., citrus fruit, strawberries, broccoli, red peppers, potato)
Thiamin (mg)	1.2	1.1	ND[7]	Grain products, pork, legumes
Riboflavin (mg)	1.3	1.1	ND[7]	Dairy products, meat, fish, legumes
Niacin (mg NE)[8]	16	14	35[9]	Meat, fish, poultry, nuts. In addition to preformed niacin, niacin equivalents can be synthesized from tryptophan, so protein foods contribute to niacin intake
Folate (µg DFE)[10]	400[11]	400[11]	1000[9]	Legumes, grain products, leafy greens, oranges
Vitamin B_6 (mg)	1.3 (≤50) 1.7 (>50)	1.3 (≤50) 1.5 (>50)	100	Meat, fish, poultry, legumes, banana, certain vegetables
Vitamin B_{12} (µg)	2.4[12]	2.4[12]	ND[7]	Animal products (meat, fish, poultry, eggs, dairy products)
Pantothenic acid (mg)	5*	5*	ND[7]	Limited data available, but it is widely distributed in the food supply
Biotin (µg)	30*	30*	ND[7]	Few data available
Choline (mg)	550*	425*	3500	Milk, liver, eggs, peanuts. Lecithin added to processed foods

* Values with an asterisk represent an AI rather than an RDA.

[1] For more information about food sources of nutrients, go to http://www.nal.usda.gov/fnic/foodcomp/Data/SR15/wtrank/wt_rank.html

[2] 1 RAE (1 Retinol Activity Equivalent) = 1 µg retinol or 3.33 IU retinol; 12 µg beta-carotene or 20 IU beta-carotene. To calculate RAE from Retinol Equivalents (RE) of beta-carotene in *foods*, divide the RE by 2. For preformed vitamin A (retinol) in foods or supplements, and for provitamin A carotenoids (e.g., beta-carotene) in *supplements*, 1 RE = 1 RAE = 3.33 IU.

[3] The UL for vitamin A applies only to preformed retinol, and not to vitamin A from carotenoids.

[4] For vitamin D, 1 µg = 40 IU.

[5] If a food or supplement is labeled in IU of vitamin E, convert to mg α-tocopherol as follows: for foods or supplements containing RRR-α-tocopherol or derivatives (also labeled as *d*-α-tocopherol), IU x 0.67 = mg α-tocopherol. For foods or supplements containing *all rac*-α-tocopherol or derivatives (also labeled as *dl*-α-tocopherol), IU x 0.45 = mg α-tocopherol.

[6] The UL for vitamin E applies to all forms of supplemental vitamin E (i.e., not just *d*-α-tocopherol).

[7] ND = not determined. The absence of a UL should not be interpreted as meaning that high intakes are safe; it simply means data were not available to identify a UL.

[8] 1 mg NE (Niacin Equivalent) = 1 mg niacin or the amount of niacin coenzyme formed from 60 mg tryptophan.

[9] The UL for niacin and folate apply only to intake from supplements or fortified foods, and not to niacin or folate occurring naturally in food. The UL for folate is in µg folic acid (rather than µg DFE).

[10] 1 µg DFE (Dietary Folate Equivalent) = 1 µg food folate, 0.6 µg folic acid with food, or 0.5 µg folic acid on an empty stomach.

[11] Women who are capable of becoming pregnant should obtain 400 µg *folic acid* (from a supplement or fortified food) in addition to intake of food folate from a varied diet.

[12] Adults over the age of 50 are recommended to obtain the majority of their vitamin B_{12} intake from a synthetic source (supplement or fortified food).

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