

### Vitamin D: Current Knowledge and Updated Dietary Recommendations

Over the past decade, considerable scientific and media attention has focused on an array of potential health benefits of vitamin D beyond bone health, as well as on messages about widespread vitamin D deficiency in North America. Heightened concern about vitamin D status has led to increased physician-ordered diagnostic blood tests and questions by the public about how much vitamin D to consume to best meet vitamin D recommendations. Late in 2010, vitamin D was spotlighted as a result of the release of updated dietary recommendations for this essential nutrient by the Institute of Medicine (IOM) Committee to Review Dietary Reference Intakes for Vitamin D and Calcium (1). Then, early in January 2011, *Dietary Guidelines for Americans, 2010*, the federal government's evidence-based nutritional guidance policy document, called vitamin D a nutrient of public health concern for children and adults, citing low dietary intake (2). Focusing on the nutritious foods that are recommended for nutrient adequacy, the Guidelines document notes that, in the US, most dietary vitamin D is obtained from fortified foods (2).

Vitamin D is called the "sunshine vitamin" because it can be synthesized in skin cells upon exposure to ultraviolet B (UVB) rays in sunlight. The term vitamin D refers to vitamin D2 (also called *ergocalciferol*) and vitamin D3 (*cholecalciferol*) (1, 3-4). Both forms of vitamin D function as pro-hormones (1, 3-4). To be metabolically active, vitamin D must undergo two hydroxylations in the body. First, it is transported to the liver where it is converted to 25-hydroxyvitamin D (25(OH)D) or *calcidiol* and then to the kidney and extra-renal sites where it is hydroxylated to 1,25-dihydroxyvitamin D (1,25(OH)2D) or *calcitriol*. Calcitriol, the biologically active hormonal form of vitamin D, enhances the efficiency of calcium and phosphorus absorption and is critical for bone health throughout life. The biological effects of calcitriol are mediated by vitamin D receptors. The discovery of these receptors and enzymes involved in calcitriol synthesis in most cells and tissues in the body suggests a wide variety of previously unsuspected physiological functions of vitamin D beyond its well-known roles in calcium and phosphorus metabolism and bone health.

#### Updated Dietary Recommendations for Vitamin D

The IOM, at the request of the US and Canadian governments, has published updated Dietary Reference Intakes (DRIs) for vitamin D (and calcium) (1) based on an extensive review

of the scientific literature (1, 5-7). According to the IOM's new report, the DRI for vitamin D for healthy Americans and Canadians aged 1 through 70 is 600 International Units (IU) per day (1). For adults aged 71 and older the vitamin D recommendation is increased to 800 IU per day because of age-related physical and behavioral changes (e.g., impaired renal function, less efficient synthesis of vitamin D in the skin, lower endogenous production of active vitamin D, age-related changes in body composition and low intake of vitamin D) (1).

The updated vitamin D recommendations assume minimal sun exposure and are based on evidence supporting vitamin D's role in bone health, not other health conditions. Also, the DRIs for vitamin D assume that recommended intakes of dietary calcium are met. The recommendations for vitamin D intake are established for generally healthy persons, not high risk individuals or those who require medical treatment for various health conditions.

The new DRIs for vitamin D represent an increase from the previous (1997) DRIs of 200 to 600 IU of vitamin D per day for various life stage groups (1, 3). However, the recommendations are not directly comparable. This is because, for the first time, the new DRIs for vitamin D are established as Estimated Average Requirements (EARs) and Recommended Dietary Allowances (RDAs) for all life stage groups except for infants younger than 12 months of age for whom Adequate Intakes (AIs) are indicated (1). In 1997, the DRIs for vitamin D were established as AIs (i.e., levels assumed to assure nutritional adequacy) because of insufficient data to determine EARs and thus calculate RDAs at that time (3). However, the large amount of new scientific data related to vitamin D accumulated in the intervening years (1, 5-7) allowed the committee to establish EARs and RDAs for vitamin D (1). The EAR represents an estimated median requirement (i.e., half the healthy population has requirements above and half below) and is used for planning intakes and assessing adequacy of intakes for population groups. The RDA, which is derived from the EAR (The EAR for vitamin D is 400 IU per day for individuals 1 year of age and older.), meets or exceeds the requirement of essentially all of the healthy population (97.5%) (1) and can be used as a guide for daily intake by individuals. [See table *Dietary Reference Intakes for Vitamin D*.]

### ***Vitamin D's Role in Health and Disease***

The importance of vitamin D for bone health is well established by scientific evidence (1-4, 8). Vitamin D helps maintain normal serum levels of calcium and phosphorus by enhancing their absorption, which in turn promotes skeletal growth and maintenance. Classic vitamin D deficiency diseases, which are rare in North America, include *rickets* in children and *osteomalacia* in adults (1, 7). Rickets is characterized by a failure of bone to properly mineralize, resulting in soft bone and skeletal deformities (e.g., bowed legs). Osteomalacia is a softening, weakening and demineralization of bones. A more common disease in adults resulting from long-term vitamin D (and calcium) deficiency is *osteoporosis*, a skeletal disorder characterized by reduced bone mass, fragility and susceptibility to fractures (4-5, 8).

In recent years, numerous studies, mostly epidemiological, have examined the association between vitamin D intake or status and non-skeletal diseases including various cancers, cardiovascular disease, hypertension, diabetes, metabolic syndrome, falls and physical performance, immune functions, infectious diseases, preeclampsia and other medical conditions (1, 4, 6-7, 9). However, the inconsistent findings and failure to establish a cause and effect relationship led the DRI committee to describe current findings regarding vitamin D and non-skeletal diseases as "hypotheses of emerging interest" (1). Thus, while recognizing that future research, particularly rigorous trials, may provide more conclusive evidence of a beneficial effect of vitamin D on various non-skeletal health outcomes, the DRI committee did not include these emerging new roles in the new recommendations.

### ***Vitamin D Status***

Serum 25(OH)D level is a well-established biomarker of total vitamin D exposure from food, supplements and synthesis from the sun. However, there is a lack of consensus regarding cut-points for serum 25(OH)D levels relative to vitamin D sufficiency, deficiency and excess. Based on recent available data, the committee considers 50 nmol/L of 25(OH)D indicative of vitamin D sufficiency for practically all people (i.e., the level consistent with the RDA), 30-50 nmol/L as indicative of risk of vitamin D inadequacy for some individuals and < 30 nmol/L as vitamin D deficient (1). Serum 25(OH)D levels above 75 nmol/L are considered to have no increased health benefit and above 125 nmol/L to be "reason for concern" (1).

Despite reports of widespread vitamin D deficiency (1, 9) and identification of vitamin D as a nutrient of public health

concern (10), the committee concluded that the requirements for vitamin D for life stage groups in both the US and Canada are being met (1). Median vitamin D intakes from foods were found to be below the EAR of 400 IU (10 µg) per day (1). However, national surveys revealed that average serum 25(OH)D levels were well above 40 nmol/L (i.e., a level consistent with intake equivalent to the EAR), and in fact were above 50 nmol/L (i.e., equivalent to the RDA) (1). The report notes that these findings suggest national policy should consider intake data in the broad context of measures of 25(OH)D, a biomarker of total vitamin D exposure, including synthesis by the body, dietary intake and supplement intake (1).

The committee suggests that the previously reported prevalence of vitamin D deficiency in the population may be overestimated as a result of higher cut-point values of 25(OH)D used to define vitamin D deficiency (1). Unfortunately, cut-points of 25(OH)D for vitamin D adequacy and deficiency have yet to be standardized. Also, there is considerable variability in how serum levels of 25(OH)D are measured and how laboratories interpret results.

Although the committee concludes that the majority of Americans and Canadians are obtaining enough vitamin D, it recognizes that certain subsets of the population, specifically older adults, may fall short of meeting vitamin D recommendations (1). Also, obese individuals, persons whose exposure to sunlight is limited (e.g., living at upper latitudes, dark skinned, institutionalized) and those who follow alternative diets (e.g., exclude dairy products) may be at risk of vitamin D deficiency.

### ***How much vitamin D is too much?***

The increasing number of vitamin D fortified foods available in the marketplace, along with the current use of vitamin D supplements, has led to concern about potential harm from consuming too much vitamin D. Prolonged sun exposure does not result in vitamin D toxicity. The DRI committee has established a Tolerable Upper Intake Level (UL) of 4,000 IU per day for all individuals aged 9 years and older, a level twice that recommended in 1997 (i.e., 2,000 IU or 50 µg per day) for this age range (1, 3). The UL is defined as the "highest average daily intake of a nutrient that is likely to pose no risk of adverse health effects for nearly all persons in the general population" (1). It reflects a long-term level of intake that will not cause harm to the normal, free-living population.

Most studies have focused on potential risks associated with

very high doses of vitamin D taken for short periods of time (i.e., acute effects). Little is known about the health effects of prolonged high intakes of vitamin D. Short-term clinical trials of vitamin D in amounts below 10,000 IU/day in healthy adults have not resulted in symptoms of toxicity. However, emerging data suggest potential adverse outcomes (e.g., all-cause mortality, some cancers, cardiovascular disease risk, fractures and falls) from vitamin D intakes lower than those associated with classic toxicity and at serum 25(OH)D levels in the range of 75 to 120 nmol/L. To ensure safety, the committee took a cautious approach in setting ULs for vitamin D.

### Sources of Vitamin D

Vitamin D can be obtained from sunlight, food and supplements. The amount of vitamin D synthesized in the skin following exposure to UVB irradiation varies widely and depends on a variety of factors. Aging, increased skin pigmentation, use of sunscreens, glass (windows), clothing, winter season, living in northern latitudes, cloud cover and smog are among the factors that decrease cutaneous synthesis of vitamin D (1). Many people minimize their exposure to sunlight due to concerns about skin cancer. Whether a desirable level of regular sun exposure exists that imposes no or minimal risk of skin cancer over time is unknown (11). The American Academy of Dermatology recommends that people obtain vitamin D from food sources and supplements, not from unprotected sun exposure, as UVB irradiation is a known risk factor for skin cancer (11).

All children, adults, and the elderly are encouraged to meet the AI for vitamin D by consuming vitamin D-rich foods in both naturally occurring and fortified forms. Children, adults, and the elderly with deficient or inadequate blood levels of vitamin D should consume more vitamin D-rich foods. Few foods naturally contain vitamin D. Some foods that do are oily marine fish (e.g., wild-caught mackerel, salmon, tuna), cod liver oil, egg yolk and sun-exposed mushrooms (1, 4, 10). The US Department of Agriculture's National Nutrient Data website, which is available at: [www.ars.usda.gov/ba/bhnrc/ndl](http://www.ars.usda.gov/ba/bhnrc/ndl), shows the nutrient content of many foods and provides a list of foods containing vitamin D ([www.ars.usda.gov/Services/docs.htm?docid=18807&pf=1&cg\\_id=0](http://www.ars.usda.gov/Services/docs.htm?docid=18807&pf=1&cg_id=0)).

In the US, fluid milk and some other dairy foods such as certain yogurts and cheeses, as well as some breakfast cereals, breads and beverages such as orange juice are fortified with vitamin D. Nearly all fluid milk sold in the US is fortified with vitamin D to obtain a standardized amount of 400 IU (10 µg) per quart. The food industry is increasingly introducing foods fortified with vitamin D. If a food is fortified with vitamin D in the US, vitamin D must be listed on the Nutrition Facts panel as a percentage of the Daily Value (DV), which is 400 IU for vitamin D. Foods that contain between 10% and 19% of the DV of vitamin D per serving are considered a *good source* of this nutrient; foods containing 20% or more of the DV per serving are considered an *excellent source*.

*Dietary Reference Intakes for Vitamin D (amount/day) (1)*

<i>Life Stage Group</i>	<i>AI</i>	<i>EAR</i>	<i>RDA</i>	<i>UL</i>
<b>Infants</b>				
0 to 6 mo	400 IU (10 µg)	---	---	1,000 IU (25 µg)
6 to 12 mo	400 IU (10 µg)	---	---	1,500 IU (38 µg)
<b>Children</b>				
1-3 y	---	400 IU (10 µg)	600 IU (15 µg)	2,500 IU (63 µg)
4-8 y	---	400 IU (10 µg)	600 IU (15 µg)	3,000 IU (75 µg)
<b>Males &amp; Females</b>				
9-70 y	---	400 IU (10 µg)	600 IU (15 µg)	4,000 IU (100 µg)
>70 y	---	400 IU (10 µg)	800 IU (20 µg)	4,000 IU (100 µg)
<b>Pregnancy &amp; Lactation</b>				
14-50 y		400 IU (10 µg)	600 IU (15 µg)	4,000 IU (100 µg)

Note: AI = Adequate Intake; EAR = Estimated Average Requirement; RDA = Recommended Dietary Allowance; UL = Tolerable Upper Intake Level; IU = International Units

According to nutrient intake data from the National Health and Nutrition Examination Survey (NHANES) 2005-2006, the US population ages 2 and older obtains slightly more than 52% of total dietary vitamin D intake from vitamin D-fortified fluid milk, milk drinks, and desserts and yogurt; 8.6% from fin fish and shellfish; 6.5% from fortified cereals; 6.2% from meat, poultry, franks, sausages and lunch meats; 5.0% from eggs and egg products and lower percentages from other foods [10 (Part D, Section 2, page 78)].

Although most healthy people can obtain recommended daily amounts of vitamin D from food, experts note that supplements of vitamin D may be needed by some individuals. Vitamin D can be found in multi-vitamin/multi-mineral supplements, as well as in single-nutrient supplements of vitamin D. To avoid exceeding the UL for vitamin D, individuals should consider their total intake of vitamin D from foods naturally containing vitamin D, vitamin D fortified foods and supplements.

In summary, the IOM has updated dietary recommendations for vitamin D for different life stage groups based on the most recent scientific evidence. Health professionals can help individuals meet their recommendations for vitamin D by educating them about dietary sources of vitamin D, encouraging regular intake of vitamin D-rich foods in both naturally occurring and fortified forms and offering individualized guidance for those who have specific health and dietary needs.

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