Vitamin D

Physiological Functions

Vitamin D is required to maintain calcium and phosphorus balance and may be involved in differentiation of bone marrow-derived progenitor cells to mature osteocytes or lymphocytes. Activation of cholecalciferol to calcitriol by two consecutive hydroxylations in liver and kidney is required for vitamin D activity. Calcitriol is a hormone-like substance exhibiting both paracrine (bone and intestinal cells) and autocrine (renal cells) activity.

Vitamin D regulates calcium and phosphorus levels by effects on the intestines, bone, and kidney. In the intestines, calcitriol binds to nuclear receptors which stimulates synthesis of mRNA for intestinal calcium-binding protein (CaBP). Calcium-binding protein increases the rate of mucosal uptake of calcium. Since membrane permeability to calcium is enhanced by vitamin D, a corresponding increased uptake of phosphorus will occur to maintain electrical neutrality. In bone, calcitriol stimulates osteoclastic activity which increases bone resorption to release calcium and phosphorus into the blood. Bone resorption must occur prior to formation and is a requisite first step in the remodeling process. In the kidney, calcitriol increases reabsorption of calcium and phosphorus.

Activation of vitamin D is directly induced by a decrease in serum phosphorus levels. Changes in serum calcium levels affect vitamin D through parathyroid hormone stimulation of renal hydroxylation. Activation of the vitamin is inhibited by increased serum phosphorus levels or increased serum levels of calcitonin. This regulatory effect of serum phosphate levels on vitamin D metabolism makes phosphorus balance an important factor in vitamin D-mediated homeostatic regulation of calcium balance.

Deficiencies

Vitamin D can be produced from precursors (cholecalciferol) in the skin by photolytic activity of ultraviolet B radiation. The amount of sun exposure required to stimulate this conversion is related to the darkness of skin with six times as much sunlight need by light-skinned compared with dark-skinned individuals. Dermal conversion is an unreliable source of vitamin D because time of exposure to sunlight is highly variable. Use of sunblock also interferes with this reaction. Because of the damaging effects of ultraviolet light, unprotected exposure to sunlight should only occur during the early morning or late evening hours when ultraviolet radiation is weakest. However, a dietary source is necessary to insure consistent availability of vitamin D.

Vitamin D deficiency can develop from poor dietary intake or limited exposure to sunlight. Since this vitamin is fat-soluble, fat malasorption syndrome may also contribute to poor vitamin D status. Strict vegetarians or those who limit milk intake are also at risk.

Rickets is the clinical manifestation of vitamin D deficiency among children while *osteomalacia* is observed among adults. These diseases are characterized by bowlegs, knock-kness, curvature of the spine, and thoracic and pelvic deformities. Convulsions and tetany may also occur in rickets, but are rarely observed with osteomalacia.

Toxicity

Hypervitaminosis D may occur with chronic intake of high doses of vitamin D supplements or fish oils. Clinical signs of toxicity include elevated serum calcium and phosphorus levels, soft tissue calcification, headache, polyuria, polydipsia, and nausea.

- *The upper limit of safety for vitamin D established by the Food and Nutrition Board of the Institute of Medicine is 25 μg (1000 IU) daily for infants and 50 μg (2000 IU) for children and adults.*

Requirements

Vitamin D is commonly measured in micrograms (μg). However, International Units (IU) is the unit of measurement for vitamin D that appears on food labels. To convert vitamin D from IU to μg, 200 IU is equivalent to 5 μg. The Daily Reference Intakes (DRI) for vitamin D are shown in the table below.

Vitamin D Requirements
Daily Reference Intakes

Life Stage	Vitamin D (μg)
Infants	
0-6 mo	5
7-12 mo	5
Children	
1-3 y	5
4-8 y	5
Males	
9-13 y	5
14-18 y	5
19-30 y	5
31-50 y	5
51-70 y	10
≥70 y	15
Females	
9-13 y	5
14-18 y	5
19-30 y	5
31-50 y	5
51-70 y	10
≥70	15
Pregnancy	
≤18 y	5
19-30 y	5
31-50 y	5

Lactation	
≤18 y	5
19-30 y	5
31-50 y	5

Dietary Sources

Natural sources of vitamin D in the food supply are few. Fish and fish oils are the richest sources of vitamin D, but amounts contributed by these foods are not reliable. Consequently, whole and skim milk are fortified with vitamin D. Other dairy products may not contain vitamin D unless fortified milk was used in their manufacture. See table below for dietary sources of vitamin D.

FOOD	Vitamin D (mcg)
Cod liver oil, 1 Tbl	34.0
Pacific oysters, 3.5 oz	16.0
Most fish, 3.5 oz	8.0
Vitamin D fortified milk	2.45
Egg, cooked	0.65
Beef, 3.5 oz	0.18
Yogurt, 1 cup	0.10
Cheddar cheese, 1 oz	0.09