

Ensuring Adequate Vitamin D Status for Patients on A Plant-Based Diet



Stewart Rose* and Amanda Strombom

Plant-based Diets in Medicine, USA

Submission: November 14, 2019; **Published:** December 03, 2019

***Corresponding author:** Stewart Rose, Plant-based Diets in Medicine, 12819 SE 38th St #427, Bellevue, WA 98006, USA

Abstract

Vitamin D is a fat-soluble vitamin that is naturally present in a few foods, added to others, and available as a dietary supplement. It is also produced endogenously when ultraviolet rays from sunlight strike the skin and trigger vitamin D synthesis. The flesh of fatty fish (such as salmon, tuna, and mackerel) and fish liver oils are among the best sources of foods that contain vitamin D naturally. Small amounts of vitamin D are also found in beef liver, cheese and egg yolks. Almost all of the U.S. dairy milk supply is voluntarily fortified with 100 IU/cup.

Since patients following a plant-based diet don't consume any of these, there has been some concern that they may run a higher risk of Vitamin D deficiency. However, studies show that on average their levels 25(OH)D are adequate. However, this shouldn't lead to complacency, since Vitamin D deficiency is widespread in the general population. Over 41% of people in a large study of all races, ethnicities and ages showed insufficient vitamin D levels. Those adults at greatest risk of vitamin D deficiency include patients with chronic illnesses, dark-pigmented skin, or poor nutrition. Vegans obtain vitamin D from sunlight, from fortified foods and supplements. Patients should be informed that they must rely on these sources and so should make sure that their intake of these foods is adequate. While Vitamin D3 comes from animal sources, vitamin D2 comes from plant sources and is equivalent in daily dosing.

Keywords: Calcidiol; Calcitriol; Calcium; Food sources; Osteomalacia; Plant-based diet; Rickets; Ultraviolet radiation; Vegan; Vitamin D

Introduction

Physiology

Vitamin D is a fat-soluble vitamin that is naturally present in very few foods, added to others, and available as a dietary supplement. It is also produced endogenously when ultraviolet rays from sunlight strike the skin and trigger vitamin D synthesis. Vitamin D obtained from sun exposure, food, and supplements is biologically inert and must undergo two hydroxylations in the body for activation. The first occurs in the liver and converts vitamin D to 25-hydroxyvitamin D [25(OH)D], also known as calcidiol. The second occurs primarily in the kidney and forms the physiologically active 1,25-dihydroxyvitamin D [1,25(OH)2D], also known as calcitriol [1]. Vitamin D promotes calcium absorption in the gut and maintains adequate serum calcium and phosphate concentrations to enable normal mineralization of bone and to prevent hypocalcemic tetany. It is also needed for bone growth and bone remodeling by osteoblasts and osteoclasts [1,2]. Without sufficient vitamin D, bones can become thin, brittle, or misshapen. Vitamin D sufficiency prevents rickets in children and osteomalacia in adults [1]. Together with calcium, vitamin D also helps protect older adults from osteoporosis [3]. Vitamin D also has other roles in the body, including modulation

of cell growth, neuromuscular and immune function, and reduction of inflammation [1,4,5]. Many genes encoding proteins that regulate cell proliferation, differentiation, and apoptosis are modulated in part by vitamin D [1]. Many cells have vitamin D receptors, and some convert 25(OH)D to 1,25(OH)2D. Given the high rate of bone development early in life, adequate serum concentrations of vitamin D are crucial for the developing child. There has also been a piquing interest in vitamin D in pediatric patients due to the recent epidemiologic reports suggesting that vitamin D may protect against autoimmune disease and play a role in innate immunity [6].

UV Source

Most people meet at least some of their vitamin D needs through exposure to sunlight [1,2]. Ultraviolet (UV) B radiation with a wavelength of 290–320 nanometers penetrate uncovered skin and converts cutaneous 7-dehydrocholesterol to previtamin D3, which in turn becomes vitamin D3 [1]. Season, time of day, length of day, cloud cover, smog, skin melanin content, and sunscreen are among the factors that affect UV radiation exposure and vitamin D synthesis [1]. Perhaps surprisingly, geographic latitude does not consistently predict average serum

25(OH)D levels in a population. Ample opportunities exist to form vitamin D (and store it in the liver and fat) from exposure to sunlight during the spring, summer, and fall months, even in the far north latitudes [1]. However, this requires spending adequate time outdoors in the sunshine, without blocking the UV radiation using clothing or sunscreen.

Food Sources

Very few foods in nature contain vitamin D. The flesh of fatty fish (such as salmon, tuna, and mackerel) and fish liver oils are among the best sources [1,7]. Small amounts of vitamin D are found in beef liver, cheese, and egg yolks. Vitamin D in these foods is primarily in the form of vitamin D3 and its metabolite 25(OH)D3 [8]. Some mushrooms provide vitamin D2 in variable amounts [9,10]. Mushrooms with enhanced levels of vitamin D2 from being exposed to ultraviolet light under controlled conditions are also available. Fortified foods provide most of the vitamin D in the American diet [1,9]. Fortification of cow’s milk with vitamin D began in the United States during the 1930s, largely as an effort to combat rickets, a major public health problem at the time [9]. Almost all milk available in the U.S. is now fortified with 100 IU/cup of vitamin D2 [11]. In Canada, milk is fortified by law with 35–40 IU/100 mL, as is margarine at ≥530 IU/100 g. However, other dairy products made from milk, such as cheese and ice cream, are generally not fortified. Ready-to-eat breakfast cereals often contain added vitamin D, as do some brands of orange juice, yogurt, margarine and other food products. Dairy-free milks, and other dairy substitutes, often have vitamin D added to them. Both the United States and Canada mandate the fortification of infant formula with vitamin D: 40–100 IU/100 kcal in the United States and 40–80 IU/100 kcal in Canada [1].

Lactation

Vitamin D requirements cannot ordinarily be met by human milk alone [12]. Breast milk contains very little vitamin D, an average of 22 units/L (range 15 to 50 units/L) in a vitamin D-sufficient mother [13]. The vitamin D content of human milk is related to the mother’s vitamin D status, so mothers who supplement with high doses of vitamin D may have correspondingly high levels of this nutrient in their milk [14]. Recent studies suggest that maternal intake of higher than recommended doses of vitamin D (4000 to 6400 units daily) may achieve vitamin D concentrations in breast milk to provide sufficient vitamin D supplementation for breastfeeding infants. However, this approach is not recommended [14,15]. While the sun is a potential source of vitamin D, the AAP (American Academy of Pediatrics) advises keeping infants out of direct sunlight and having them wear protective clothing and sunscreen [16].

Deficiency

The disease of rickets is fortunately rare today, but it does still occur. A review of reports of nutritional rickets found that

a majority of cases occurred among young, breastfed African Americans [17]. A survey of Canadian pediatricians found the incidence of rickets in their patients to be 2.9 per 100,000; almost all those with rickets had been breastfed [18]. Due to the low vitamin D concentrations found in breast milk, and the advice to avoid the sun, the newest recommendation for exclusively and partially breastfed infants is to provide a supplement of 400 units per day to the infant (increased from 200 units per day) [3,14]. While rickets is rare, unfortunately, Vitamin D deficiency remains a significant problem. Large percentages of people in all races, ethnicities, and ages show a high prevalence of Vitamin D deficiency. In one study, insufficient vitamin D levels were found in 41.6% of a large sample size. Race was identified as a significant risk factor, with African American adults having the highest prevalence rate of vitamin D deficiency at 82% followed by Hispanic adults at 63% [11,19].

Those adults at greatest risk of vitamin D deficiency include patients with chronic illnesses (e.g., chronic kidney disease, cystic fibrosis, asthma, and sickle cell disease), dark-pigmented skin, poor nutrition [6,20,21]. Chronic use of certain medications (e.g., glucocorticoids, cytochrome P450 3A4 inducers, anticonvulsants, and anti-retroviral agents) has also been associated with compromised vitamin D concentrations [6].

Diagnosis

Table 1: Serum 25-Hydroxyvitamin D [25(OH)D] Concentrations and Health* [1].

nmol/L**	ng/mL*	Health status
<30	<12	Associated with vitamin D deficiency, leading to rickets in infants and children and osteomalacia in adults
30 to <50	12 to <20	Generally considered inadequate for bone and overall health in healthy individuals
≥50	≥20	Generally considered adequate for bone and overall health in healthy individuals
>125	>50	Emerging evidence links potential adverse effects to such high levels, particularly >150 nmol/L (>60 ng/mL)

*Serum concentrations of 25(OH)D are reported in both nanomoles per liter (nmol/L) and nanograms per milliliter (ng/mL). ** 1 nmol/L = 0.4 ng/mL

Serum concentration of 25(OH)D is the best indicator of vitamin D status. It reflects both vitamin D produced cutaneously and that obtained from food and supplements [1] and has a fairly long circulating half-life of 15 days [B]. 25(OH)D functions as a biomarker of exposure, but it is not clear to what extent 25(OH)D levels also serve as a biomarker of effect (i.e.,

relating to health status or outcomes) [1]. Serum 25(OH)D levels do not indicate the amount of vitamin D stored in body tissues. In contrast to 25(OH)D, circulating 1,25(OH)2D is generally not a good indicator of vitamin D status because it has a short half-life of 15 hours and serum concentrations are closely regulated by parathyroid hormone, calcium, and phosphate [22]. Levels of 1,25(OH)2D do not typically decrease until vitamin D deficiency is severe [2,6]. Desirable concentrations of Serum 25-Hydroxyvitamin D (25(OH)D) (Table 1).

Vegans

While there has been some concern that vegans and vegetarians might have inadequate levels of 25(OH)D, studies have shown that vegans do have adequate levels. Therefore, vegans do not run a risk of deficiency any higher than their meat-eating counterparts or require more monitoring or intervention. A study of Danish vegans showed that they had an average 57nmol/l 25(OH)D [23]. This result is similar to a British study which showed that vegans had an average 25(OH)D of 56 nmol/l 25(OH)D [24]. An American study of a group containing both vegetarians and vegans showed an average level of 25(OH)D at 77nmol/l [25].

Supplements D2 vs D3

In supplements and fortified foods, vitamin D is available in two forms, D2 (ergocalciferol) and D3 (cholecalciferol) that differ chemically only in their side-chain structure. Vitamin D2 is manufactured by the UV irradiation of ergosterol in yeast, and vitamin D3 is manufactured by the irradiation of 7-dehydrocholesterol from lanolin and the chemical conversion of cholesterol [6]. Vitamin D2 has been the mainstay for the prevention and treatment of vitamin D deficiency in children and adults for more than 90 years [6,26]. As little as 100 IU vitamin D2 was found to be effective in the prevention of rickets [26-28]. It is commonly used for supplementation and food fortification. Vitamin D2 is more acceptable to those on a plant-based diet because it is not derived from animals. Vitamin D3 is the endogenous form of vitamin D produced by keratinocytes in the skin in response to ultraviolet B radiation from sunlight. Both forms of vitamin D are hydroxylated in the liver to 25(OH)D. It has been suggested that vitamin D3 may be superior to vitamin D2 in sustaining adequate 25(OH)D values in adults [29,30] because 25(OH)D2 may bind less avidly to vitamin D binding protein and be cleared more rapidly than 25(OH)D3. However, others have found that regular supplementation with both forms of vitamin D, at common doses of say 1000 IU daily, were equally effective in maintaining 25(OH)D levels [31,32].

In children, both vitamins D2 and D3 similarly increase serum 25(OH)D concentrations in rachitic and healthy children [33]. Even if vitamin D3 was more efficacious than vitamin D2 under special circumstances, it can still be used with equal efficacy by simply raising the dose of D2. Both vitamin D2 and vitamin D3 are available as supplements, but only vitamin D2 is available

as a pharmaceutical preparation because its use predated the Food and Drug Administration and was thus grandfathered as a pharmaceutical drug. Vitamin D3 was commercially developed in the 1950s and has not been approved as a pharmaceutical agent in the United States, but it is used in food supplementation and vitamin supplements.

Toxicity

Vitamin D toxicity can cause non-specific symptoms such as anorexia, weight loss, polyuria, and heart arrhythmias. More seriously, it can also raise blood levels of calcium which leads to vascular and tissue calcification, with subsequent damage to the heart, blood vessels, and kidneys [1]. A serum 25(OH)D concentration consistently >500 nmol/L (>200 ng/mL) is considered to be potentially toxic [22]. Excessive sun exposure does not result in vitamin D toxicity because the sustained heat on the skin is thought to photodegrade previtamin D3 and vitamin D3 as it is formed [6]. In addition, thermal activation of previtamin D3 in the skin gives rise to various non-vitamin D forms that limit formation of vitamin D3 itself. Some vitamin D3 is also converted to nonactive forms [1]. Intakes of vitamin D from food that are high enough to cause toxicity are very unlikely. Toxicity is much more likely to occur from high intakes of dietary supplements containing vitamin D.

Most reports suggest a toxicity threshold for vitamin D of 10,000 to 40,000 IU/day and serum 25(OH)D levels of 500–600 nmol/L (200–240 ng/mL). While symptoms of toxicity are unlikely at daily intakes below 10,000 IU/day, the FNB pointed to emerging science from national survey data, observational studies, and clinical trials suggesting that even lower vitamin D intakes and serum 25(OH)D levels might have adverse health effects over time. The FNB concluded that serum 25(OH)D levels above approximately 125–150 nmol/L (50–60 ng/mL) should be avoided, as even lower serum levels (approximately 75–120 nmol/L or 30–48 ng/mL) are associated with increases in all-cause mortality, greater risk of cancer at some sites like the pancreas, greater risk of cardiovascular events, and more falls and fractures among the elderly. The FNB committee cited research which found that vitamin D intakes of 5,000 IU/day achieved serum 25(OH)D concentrations between 100–150 nmol/L (40–60 ng/mL), but no greater. Applying an uncertainty factor of 20% to this intake value gave an upper limit of 4,000 IU which the FNB applied to children aged 9 and older and adults, with corresponding lower amounts for younger children [34].

Discussion

Vitamin D deficiency is widespread. With declining milk consumption levels, and more care being taken to limit sun exposure, this problem is likely to get worse across the US population. Concern by some physicians that those patients who follow a vegan diet need different measures for the prevention and treatment of vitamin D deficiency seems unwarranted. Studies of vegans have shown that, on average, their 25(OH)D

levels are within the recommended range. They are, therefore, not any more likely to be vitamin D deficient than any other patient. The vegan patients should maintain their 25(OH)D in the recommended range the same as any other patient. Vitamin D2 is as effective as Vitamin D3 for the prevention and treatment of vitamin D deficiency, as well as for preventing related disease such as rickets, so vegan patients can safely be treated with Vitamin D2.

Research on vitamin D and other pathologies such as cancer and diabetes are ongoing. We await their results. In the meantime, maintaining adequate levels of 25(OH)D in patients may be preventing pathologies other than osteomalacia and rickets.

Conflict of Interest

The authors state that they have no conflict of interest.

References

1. Ross AC, Taylor CL, Yaktine AL, Del Valle HB, et al. (2010) Dietary Reference Intakes for Calcium and Vitamin D. Institute of Medicine (US) Food and Nutrition Board.
2. Cranney C, Horsley T, O'Donnell S, Weiler H, Puil L, et al. (2007) Effectiveness and safety of vitamin D in relation to bone health. Rockville, MD: Evid Rep Technol Assess (Full Rep) 158: 1-235.
3. Misra M, Pacaud D, Petryk A, Collett-Solberg P, Kappy M, et al. (2008) Vitamin D deficiency in children and its management: review of current knowledge and recommendations. *Pediatrics* 122(2): 398-417.
4. Holick M (2005) Vitamin D. In: Shils M, Shike M, Ross A, Caballero B, Cousins R, eds. *Modern Nutrition in Health and Disease*. 10th ed. Philadelphia, PA: Lippincott Williams & Wilkins, USA.
5. Norman A, Henry H (2006) Vitamin D. In: Bowman B, Russell R, eds. *Present Knowledge in Nutrition*. 9th ed. ILSI Press, Washington DC, USA.
6. Holick M (2007) Vitamin D Deficiency. *New Eng J Med* 357(3): 266-281.
7. US Department of Agriculture, Agricultural Research Service. USDA National Nutrient Database for Standard Reference: Nutrient Data Laboratory; 2011. Release 24.
8. Ovesen L, Brot C, Jakobsen J (2003) Food contents and biological activity of 25-hydroxyvitamin D: a vitamin D metabolite to be reckoned with? *Ann Nutr Metab* 47(3-4): 107-113.
9. Calvo M, Whiting S, Barton C (2004) Vitamin D fortification in the United States and Canada: current status and data needs. *Am J Clin Nutr* 80(6 Suppl): 1710S-1716S.
10. Mattila P, Piironen V, Uusi-Rauva E, Koivistoinen P (1994) Vitamin D Contents in Edible Mushrooms. *Agric Food Chem* 42(11): 2449-2453.
11. Parva N, Tadepalli S, Singh P, Qian A, Joshi R, et al. (2018) Prevalence of Vitamin D Deficiency and Associated Risk Factors in the US Population (2011-2012). *Cureus* 10(6): e2741.
12. Picciano MF (2001) Nutrient composition of human milk. *Pediatr Clin North Am* 48(1): 53-67.
13. Leerbeck E, Sondergaard H (1980) The total content of vitamin D in human milk and cow's milk. *Br J Nutr* 44(1): 7-12.
14. Wagner C, FR G (2008) American Academy of Pediatrics Section on Breastfeeding. Prevention of rickets and vitamin D deficiency in infants, children, and adolescents. *Pediatrics*. Nov 122(5): 1142-1152.
15. Basile L, Taylor S, Wagner C, Horst R, Hollis B (2006) The effect of high-dose vitamin D supplementation on serum vitamin D levels and milk calcium concentration in lactating women and their infants. *Breastfeed Med* 1(1): 27-35.
16. American Academy of Pediatrics Committee on Environmental Health (1999) Ultraviolet light: a hazard to children. *Pediatrics* 104(2 Pt 1): 326-333.
17. Weisberg P, Scanlon K, Li R, Cogswell M (2004) Nutritional rickets among children in the United States: review of cases reported between 1986 and 2003. *Am J Clin Nutr* 80(6 Suppl): 1697S-1705S.
18. Ward L, Gaboury I, Ladhani M, Zlotkin S (2007) Vitamin D-deficiency rickets among children in Canada. *Can Med Assoc J* 177(2): 161-166.
19. Forrest K, Stuhldreher W (2011) Prevalence and correlates of vitamin D deficiency in US adults. *Nutr Res* 31(1): 48-54.
20. Lebrun J, Moffatt M, Mundy R, Sangster RK, Postl BD, et al. (1993) Vitamin D deficiency in a Manitoba community. *Can J Pub Health* 84(6): 394-396.
21. Zhou C, Assem M, Tay JC, Watkins PB, Blumberg B, et al. (2006) Steroid and xenobiotic receptor and vitamin D receptor crosstalk mediates CYP24 expression and drug-induced osteomalacia. *J Clin Invest* 116(6): 1703-1712.
22. Jones G (2008) Pharmacokinetics of vitamin D toxicity. *Am J Clin Nutr* 88(2): 582S-586S.
23. Hansen T, Madsen M, Jørgensen N, Cohen AS, Hansen T, et al. (2018) Bone turnover, calcium homeostasis, and vitamin D status in Danish vegans. *Eur J Clin Nutr* 72(7): 1046-1054.
24. Crowe FL, Steur M, Allen N, Appleby P, Travis R, et al. (2011) Plasma concentrations of 25-hydroxyvitamin D in meat eaters, fish eaters, vegetarians and vegans: results from the EPIC-Oxford study. *Public Health Nutr* 14(2): 340-346.
25. Chan J, Jaceldo-Siegl K, Fraser GE (2009) Serum 25-hydroxyvitamin D status of vegetarians, partial vegetarians, and nonvegetarians: the Adventist Health Study-2. *Am J Clin Nutr* 89(5): 1686S-1692S.
26. Eliot M, Park E (1938) Rickets. *Brennerman's Practice of Pediatrics*. Vol 1. Hagerstown, MD: WF Prior.
27. Holick MF (2006) Resurrection of Vitamin D deficiency and rickets. *J Clin Invest* 116(8): 2062-2072.
28. Jeans P (1950) Vitamin D. *JAMA* 143: 177-181.
29. Armas L, Hollis B, Heaney R (2004) Vitamin D2 is much less effective than vitamin D3 in humans. *J Clin Endocrinol Metab* 89(11): 5387-5391.
30. Trang H, Cole D, Rubin L, Pierratos A, Siu S, et al. (1998) Evidence that vitamin D3 increases serum 25-hydroxyvitamin D more efficiently than does vitamin D2. *Am J Clin Nutr* 68(4): 854-858.
31. Holick M, Biancuzzo R, Chen T, Ellen K Klein, Azzie Young, et al. (2008) Vitamin D2 is as effective as vitamin D3 in maintaining circulating concentrations of 25-hydroxyvitamin D. *J Clin Endocrinol Metab* 93(3): 677-681.
32. Gordon C, Williams A, Feldman H, Jessica May, Linda Sinclair, et al. (2008) Treatment of Hypovitaminosis D in Infants and Toddlers. *J Clin Endocrinol Metab* 93(7): 2716-2721.
33. Thacher T, Fischer P, Obadofin M, Levine M, Singh R, et al. (2010) of metabolism of vitamins D2 and D3 in children with nutritional rickets. *J Bone Miner Res* 25(9): 1988-1995.
34. National Institutes of Health Office of Dietary Supplements (2019) Vitamin D Fact Sheet for Health Professionals. Factsheets. Nov 2018.



This work is licensed under Creative Commons Attribution 4.0 License
DOI: [10.19080/OROAJ.2019.15.555913](https://doi.org/10.19080/OROAJ.2019.15.555913)

**Your next submission with Juniper Publishers
will reach you the below assets**

- Quality Editorial service
- Swift Peer Review
- Reprints availability
- E-prints Service
- Manuscript Podcast for convenient understanding
- Global attainment for your research
- Manuscript accessibility in different formats
(Pdf, E-pub, Full Text, Audio)
- Unceasing customer service

Track the below URL for one-step submission
<https://juniperpublishers.com/online-submission.php>