Vitamin D Deficiency

Description/Etiology
Vitamin D deficiency is defined by most experts as a serum 25-hydroxy vitamin D level that is < 20 ng/mL. Vitamin D deficiency was first described as the cause of rickets, a disorder that involves defective mineralization of growing bone due to an inadequate supply of calcium, phosphate, or vitamin D. Vitamin D (also referred to as calcitriol) is both a vitamin and a hormone that allows for the intestinal absorption of calcium and its deposition in bone tissue. Vitamin D is required in adequate amounts throughout the life span and especially during pregnancy for optimal fetal development to promote normal skeletal development and maintenance. Both calcium and vitamin D are needed for proper bone mineralization. Bone-related complications of vitamin D deficiency include osteomalacia, osteoporosis, fracture, and other injuries.

In addition to its role in skeletal development and maintenance, vitamin D is a key component in the process of cell differentiation and proliferation. Vitamin D has immunomodulatory and anti-infective properties, and may play a role in protecting vascular status. It is an important nutrient for prevention of cancer, diabetes mellitus, and autoimmune disorders (e.g., multiple sclerosis [MS], inflammatory bowel disease, rheumatoid arthritis); vitamin D deficiency can increase risk of developing these chronic diseases. Vitamin D deficiency is associated with increased risk for dementia, depression, Alzheimer’s disease, diabetic-related peripheral neuropathy, stroke, cerebrovascular and cardiovascular disease, and all-cause mortality.

The main source of vitamin D comes from synthesis in the skin by sunlight exposure to ultraviolet B (UVB) rays, which accounts for 80–90% of vitamin D in most persons. Vitamin D can also be obtained through dietary intake, including from animal sources (e.g., oily fish, egg yolks), fortified foods (e.g., breakfast cereals), and supplements.

Vitamin D deficiency is diagnosed in the laboratory. Serum studies are typically ordered if the patient’s clinical status raises suspicion of deficiency (e.g., the patient presents with a pattern of bone fractures and/or falls; bone deformities; failure to thrive in infants). Imaging studies can identify the extent of bone involvement in patients with vitamin D deficiency. Treatment aims to correct vitamin D deficiency with supplementation and adequate sunlight exposure.

Facts and Figures
The prevalence of vitamin D deficiency in the general population is unknown. Without vitamin D, just 10–15% of dietary calcium is absorbed.

Risk Factors
Risk factors for vitamin D deficiency include poverty, poor nutrition, residence at latitudes higher than 38°, and insufficient exposure to sunlight. Adolescents can be at increased risk, particularly adolescents who make poor food choices. Consumption of soft drinks and junk food instead of milk, orange juice, and vitamin D-fortified foods, such as breakfast cereals, can lead to vitamin D deficiency. Vitamin D deficiency is common in pregnant women and can result in rickets in the infant. Breastfed infants and older adults (i.e., who are > 65 years) are at risk of developing vitamin D deficiency. Especially at risk are individuals who have chronic conditions such as kidney failure, osteoporosis, and liver dysfunction; eat an...
inadequate diet; or are bedridden and have insufficient exposure to direct sunlight. Vitamin D malabsorption can develop in persons with celiac disease, short bowel syndrome, or cystic fibrosis. Individuals who are obese (particularly those with visceral obesity) are at risk for vitamin D deficiency, possibly due to decreased bioavailability secondary to enhanced uptake by adipose tissue. Individuals with darker skin, which filters out much of the UV light from the sun, are at higher risk for vitamin D deficiency than individuals with lighter skin. Individuals who take cholestyramine, colestipol, and anticonvulsants, such as orlistat, are at increased risk for vitamin D deficiency.

**Signs and Symptoms/Clinical Presentation**

Failure to thrive, lethargy, and increased irritability can be signs that an infant is vitamin D-deficient. Older children, adolescents, and adults with vitamin D deficiency can have increased bone fractures due to failed mineralization of bones. Stunted linear growth can develop as a result of vitamin D deficiency during periods of incremental growth (e.g., during infancy and adolescence).

**Nutritional Assessment**

› **Patient Medical History**
  • Obtain patient history, including assessing for/asking about
    – patient and family history of certain conditions known to be associated with vitamin D deficiency (e.g., kidney failure, osteoporosis, liver dysfunction, celiac disease, short bowel syndrome, cystic fibrosis, and obesity)
    – signs and symptoms (e.g., pain, fatigue, headaches), if any, that can indicate inadequate nutrient consumption and can negatively affect dietary intake
    – exposure to sunlight, which can be affected by lifestyle habits and geographic location
    – level and type of regular physical activity

› **Physical Findings of Particular Interest**
  • Patients may present with deformity of long bones (e.g., bowed legs), spinal kyphosis (e.g., a skeletal deformity), and unsteady gait (e.g., limping or waddling)

› **Patient Dietary History**
  • Evaluate usual nutrition intake by asking the patient (or patient’s family) to complete a 24-hour dietary recall identifying foods generally consumed, food preferences, cultural/religious beliefs, and medically prescribed dietary interventions
  – In the outpatient setting, a 24-hour dietary recall when combined with a three-day diet history may be a useful tool for evaluating the patient’s dietary strengths and weaknesses (i.e., patient recall of all foods and beverages consumed in a three-day period that includes one weekend day)
  • Ask about personal habits, including alcohol, caffeine, and soda consumption; tobacco use; eating at night; and frequenting vending machines or fast food restaurants and use of any herbal or over-the-counter supplements (e.g., fish oil caps, cranberry caps, ginger) as well as prescription medications
  • If the patient is an infant or child, ask the parents about the infant’s/child’s feeding history, including whether he/she was exclusively breastfed or received formula

› **Anthropometric Data**
  • Calculate the patient’s body mass index (BMI) by dividing body weight (kilograms) by height (meters squared); or 703 multiplied by weight (pounds) and divided by height (inches squared)
    – Underweight: < 18.5; **normal: 18.5–24.9**; overweight: 25–29.9; obese: > 30
    – In patients over 65 years of age, evidence suggests that a slightly higher BMI (25–27) may help prevent bone deterioration and is associated with a lower risk of mortality
    – In some cases, body composition testing (e.g., dual-energy X-ray absorptiometry scan, skin calipers) may be necessary
  • Anthropometric tools are available for the measurement of adequate nutrition in children
    – The U.S. CDC has established references for weight and growth patterns, which can be tracked on weight-for-age/height-for-age/weight-for-height age-based growth charts, as well as BMI for age charts that assist in the calculation of BMI for ages 2 to 20 years
  • Significant undesirable weight changes are as follows: +/-5% during a 30-day period or +/-10% during a 180-day period
    – Weight loss of 10–20% in a 180-day period indicates moderate protein-calorie malnutrition
    – Weight loss of > 20% in 180-day period indicates severe protein-calorie malnutrition
    – Fluid retention can impact weight variables and should be taken into account when considering the significance of weight changes
• Estimate daily energy requirements in calories (kcal) by calculating the resting metabolic rate (RMR), also called basal energy expenditure, by use of the Harris-Benedict equation (for individuals with a BMI < 30) or the Mifflin-St. Jeor equation (for obese individuals), multiplied by the appropriate activity factors (AFs) and injury factors (IFs) as shown below

- Lb/kg and in/cm conversion: 1 lb = 2.2 kg; 1 in = 2.54 cm
- Harris-Benedict Equation (for individuals with a BMI ≤ 30)
  - Men: RMR = 66 + 13.8(weight in kg) + 5.0(height in cm) - (6.8 x age)
  - Women: RMR = 655 + 9.6(weight in kg) + 1.8(height in cm) - (4.7 x age)
- Mifflin-St. Jeor Equation (for individuals with a BMI > 30)
  - Men: RMR = 10 x (weight in kg) + 6.25 x (height in cm) x age + 5
  - Women: RMR = 10 x (weight in kg) + 6.25 x (height in cm) - 5 x age – 161
- Daily kcal requirement = RMR x AF x IF
  - AF: Confined to bed: 1.2; moderately active: 1.3; active: 1.4
  - IF: Minor surgery: 1.2; skeletal trauma: 1.3; major sepsis: 1.6; severe burn: 2.1
- To encourage weight gain or loss (of 1–2 lbs/week), add or subtract 500 kcal/day, respectively, and monitor for weight changes

› Laboratory Tests and Diagnostic Tests of Particular Interest to the Nutritionist
  • Serum study results may show low levels of serum calcium and phosphorus
  • Secondary hyperparathyroidism, a syndrome of overactive secretion of parathyroid hormone, may be present due to low calcium levels secondary to vitamin D deficiency
  • Serum vitamin D levels that are below 10–20 ng/mL indicate a deficiency
  • UA may show low excretion of calcium and creatinine
  • Histologic analysis of bone tissue (usually biopsied from the iliac crest) using special stains (e.g., von Kossa stain) may show an excessive amount of osteoid formation

› Other Diagnostic Tests/Studies
  • X-rays may show evidence of generalized demineralization of bone; X-ray studies of the vertebrae may indicate a compression fracture

Treatment Goals
› Correct Vitamin D Deficiency and Reduce Risk of Complications
  • Review results of laboratory tests and diagnostic studies related to nutritional status and evaluate for deficiencies in nutrition; report findings to the treating clinician
  • Clinician may prescribe vitamin D supplements if levels are low
    – 400 IU/day to 50,000 IU/week for several weeks may be prescribed depending on the underlying cause of deficiency
    – Patients with hepatic failure, patients with an intestinal fat malabsorption syndrome, and patients who take certain medications such as cholestyramine, colestipol, and orlistat may require substantially higher doses of vitamin D
    – Calcium supplements may be prescribed to optimize bone mineralization
  • Monitor weight fluctuation and encourage weight management

› Educate on Nonpharmacological Measures for Correcting Vitamin D Deficiency
  • Review diet history information to assess dietary intake and patterns and provide detailed patient education regarding importance of following a calorie-appropriate and nutrient-dense diet; the effect of diet, exercise, sun exposure, and other lifestyle factors on vitamin D status, weight, and related medical conditions; and strategies for meal planning, grocery shopping, and food preparation. (For more information, see What Do I Need to Tell the Patient/Patient’s Family? and Discharge Planning, below)
  • Assess patient’s/family’s anxiety level and coping ability, and educate about ways to promote emotional well-being and improve quality of life (e.g., regular exercise and good nutrition)
    – Request referral to a social worker, if appropriate, for identification of local resources for dietary education, in-home resources (e.g., meal delivery)

Food for Thought
› Full-body exposure to 10–15 minutes of sunlight by a light-skinned individual in the summer months provides 10,000–20,000 IU of vitamin D; appropriate use of sunscreen should be considered
Vitamin D deficiency is associated with an increased risk for certain cancers, including colorectal, prostate, ovary, and breast cancers, as well as higher resultant mortality.

- In a study of 195 patients with cancer, researchers reported that 74% of patients had circulating vitamin D levels that were considered deficient or suboptimal; low vitamin D levels were an independent risk factor for advanced stage cancer (Churilla et al., 2012).
- Vitamin D deficiency was found in 96% of women with breast cancer in India, compared to 77% of women in the control group. Results of study in China indicated severe vitamin D deficiency in 95% of breast cancer patients, compared to 80% of women without breast cancer (Malek et al., 2013).
- Results of a prospective study revealed a significant positive association between vitamin D deficiency and risk of all-caused dementia and Alzheimer’s disease. Compared with individuals with normal vitamin D levels, participants who were deficient in vitamin D experienced a 53% greater risk of all-cause dementia and a 69% greater risk of Alzheimer’s (Littlejohns et al., 2014).

**Red Flags**

- Although extremely rare, vitamin D intoxication (diagnosed when serum levels exceed 150 ng/mL) can result from ingestion of more than 50,000 IU per day.
- The American Academy of Pediatrics recommends that breastfed infants receive 400 IU/day of vitamin D beginning before two months of age.

**What Do I Need to Tell the Patient/Patient’s Family?**

- Educate on the nutritional implications of vitamin D deficiency and the rationale for diet therapy; supplement verbal education with written information, if available.
- As tolerated, eat a calorie-appropriate diet that includes fish, lean proteins, unsaturated fats (including omega-3), complex carbohydrates (e.g., whole unrefined grains), legumes, nuts and seeds, and a variety of fruits and vegetables. (For more information on eating a balanced diet, see the United States Department of Agriculture (USDA) food guidance system, MyPlate, at [http://www.choosemyplate.gov/](http://www.choosemyplate.gov/))
  - Include natural sources of vitamin D, such as fish liver oils, fatty fish (e.g., salmon, mackerel, tuna, sardines), eggs, milk, some cereals, and mushrooms.
  - Consume meals containing a variety of at least five fruits and vegetables a day in order to supply ample vitamins, minerals, phytonutrients (i.e., beneficial plant-derived nutrients), and fiber. Eat a variety of deeply colored fruits and vegetables (e.g., spinach, carrots, berries).
  - Eat 25–30 g of fiber/day (food sources: oat bran, barley, nuts, seeds, beans, lentils, peas, and fruits and vegetables). At least half of all grains consumed should be whole grains.
  - Consume fish, especially oily fish, at least twice a week. Fish is a great source of vitamin D and omega-3, an unsaturated fat that has many health benefits, including reduced risk for cardiovascular disease (CVD). (Note: Plant sources of omega 3 include soybean, walnuts, canola, and flaxseed).
  - Ingest adequate calcium (at least 1,200 mg/day) to reduce risk for osteoporosis and CVD; good calcium sources are dairy products, fish with bones, broccoli, and legumes.
  - Reduce risk for CVD, cancer, DM2, and stroke by choosing unsaturated fats (including omega-3 fatty acid) and by limiting total fat intake to 30% or less of daily calories, limiting saturated fat (found in meat, whole milk, cream, butter, and cheese) to less than 10% of daily calories, and consuming less than 200 mg of cholesterol per day.
- Encourage adolescents to drink vitamin D–rich beverages such as milk and juice instead of caffeinated beverages.
- Reinforce the importance of taking supplemental vitamins as prescribed.
- Encourage the patient/family to adhere to recommended guidelines for sun exposure: approximately 5–30 minutes of sunlight exposure (depending on such factors as time of year, time of day, latitude, and pigmentation of skin) at least twice a week.
- Participate in regular moderate physical activity of at least 150 minutes each week, including strength training at least two days each week, if medically appropriate.
- Advise patient/family that treatment can be monitored by following bone biochemistry until correction of serum vitamin D, calcium, and phosphorus levels is observed.
- Recruit the help of family and friends to assist in meal planning, grocery shopping, and food preparation.
Related Guidelines

The U.S. Institutes of Medicine (IOM) guidelines for daily vitamin D intake in order to maintain adequate serum calcium and phosphorus concentrations are as follows:

- Birth to 1 year: 400 IU (40 IU vitamin D = 1 microgram [mcg])
- 1–70 years: 600 IU
- > 70 years: 800 IU

The tolerable upper intake levels of vitamin D are as follows:

- Birth to 6 months: 1,000 IU
- 7–12 months: 1,500 IU
- 1–3 years: 2,500 IU
- 4–8 years: 3,000 IU
- ≥ 9 years: 4,000 IU

References