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Vitamin D Supplements Review (Including Calcium, Magnesium, Vitamin K, and Boron)

Find the Best Vitamin D Supplement and Avoid Problems

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Updated July 15, 2025 ⓘ

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Summary

- **What does vitamin D do?** There are many reasons to make sure you're getting sufficient, but not excessive, vitamin D: These include improved bone health, reduced risk of heart attack and stroke, reduced risk of asthma and allergy, reduced inflammation, *possibly*, a reduced risk of prostate cancer, and perhaps others. Not surprisingly, over given periods of time there are fewer deaths among people who have the right amount of vitamin D compared to those who have too little or too much. For details, see What It Does.

- **How much vitamin D do I need?** You may already get enough vitamin D from the sun (about 15 minutes to the face, arms, and hands at least twice a week without sunscreen) and the foods you normally eat. The recommended daily allowance is 15 mcg (600 IU) for teens and adults, increasing to 20 mcg (800 IU) for those over age 70. If you're not sure, get your blood level checked by your doctor. A total serum 25-hydroxyvitamin D level of at least 20 ng/mL (equivalent to 50 nmol/L) is considered "sufficient," although there may be additional benefit to being in the 25 to 35 ng/mL range. Don't exceed 39 ng/mL. Be aware that people who are Black generally have lower total vitamin D levels than whites, but research suggests these lower levels may be sufficient for Blacks. For details see How Much Do You Need and How Much is Too Much?

- **What *form* of vitamin D is best?** Vitamin D_2 or D_3 will raise your vitamin D level, but D_3 is preferable as it may raise levels more effectively over time and is less likely to cause erroneously low vitamin D blood test results.

  Vitamin D supplements are sold as tablets, chewable tablets, capsules, gummies, softgels or liquids. Vitamin D sprays are also sold and can be as effective as a pill or liquid drops, although they tend to be more expensive.

- **Which vitamin D supplement is best?** Among the vitamin D-containing supplements that CL tested and Approved for Quality (see What CL Found and How Products Were Evaluated), CL selected ***Top Picks*** for vitamin D as well as combination products based on superior quality, dosage, price, and convenience of use. (In addition to the products tested in this review, other products discussed include *Bronson Vitamin D3 10,000*

IU, *Jarrow Formulas BoneUp*, *Member's Mark [Sam's Club] Vitamin D-3 2000 IU*, *Spring Valley Vitamin D3 25 mcg*, and *Webber Naturals Calcium Citrate Vitamin D3*.)

- **When to take vitamin D:** Take vitamin D supplements with your biggest meal of the day (the one that contains most fats and oils) as this can increase absorption by as much as 50%! For details, see Take Vitamin D with Food.
- **How much vitamin D should I take?** For every 1 ng/mL increase, you'll need to get an additional 100 IU of vitamin D per day (obese individuals may require double the amount, and if you already have an adequate level, enzymes in your body act to make it harder to raise it). For example, if your blood level is 18 ng/mL, taking 1,000 IU of vitamin D daily (or 1,600 IU if you are obese) should get you to about 28 ng/mL. It can take 6 weeks to reach the peak. Keep taking the vitamin D to stay at that level. The tolerable upper intake level (UL) of vitamin D for teens and adults, above which there is increased risk of toxicity, is 100 mcg (4,000 IU). For details, see What to Consider When Using.
- **Don't overdo it! Vitamin D safety and side effects:** Studies show that people with the highest levels of vitamin D tend to have more bone fractures, fall more frequently, sleep less well, and die sooner than those with lower, but sufficient, levels. If your level is over 20 ng/mL, you probably don't need a supplement. If your level is above 35 ng/mL, taking a supplement may be doing more harm than good, so consider cutting back. For details see How Much Do You Need and How Much is Too Much?

Products tested in 2024 and 2025

What It Is:

Vitamin D is a fat-soluble vitamin. There are two major forms of vitamin D found in food and supplements: D_2 (ergocalciferol) and D_3 (cholecalciferol). Both vitamin D_2 and D_3 appear to be absorbed with equal efficiency, and both can raise levels of 25-hydroxyvitamin D (also known as calcifediol or calcidiol), which is the prehormone form of vitamin D and a clinical measure of vitamin D status. However, there is evidence that D_3 may be more efficient at raising 25-hydroxyvitamin D levels than D_2 (see "D_2 or D_3?"). There is also evidence that calcifediol can raise 25-hydroxyvitamin D levels more efficiently than D_3 (see "D_3 or calcifediol?"). Be aware, however, that calcifediol is only sold as a prescription drug in the U.S., as is also the case with the active hormone form of vitamin D, calcitriol. However, calcifediol can be found in animal-based foods, as it is present in animal muscle and adipose (fat) tissue.

Vitamin D_3 is produced naturally in human skin exposed to ultraviolet B light and occurs in some animal products, such as cod liver oil, and, in smaller amounts, in other fatty (oily) fish such as herrings, mackerel, sardines, and salmon. Vitamin D_3 is the most common form used in dietary supplements and is the form generally used to fortify foods such as milk (which naturally contains a small amount of vitamin D_3). Vitamin D_3 is made by the conversion of cholesterol compounds, such as 7-dehydroxycholesterol from lanolin found in sheep's wool. Vitamin D_2 is made by the conversion of a sterol found in plants and yeast. Vitamin D_2 is used in some dietary supplements.

See ConsumerTips™ for more information about the two forms of vitamin D and dosing.

(See separate reviews of Calcium, Vitamin K, Magnesium, and Boron which are also used in bone health).

What It Does:

Vitamin D Deficiency

As discussed below, getting adequate vitamin D is important for bone health, and certain aspects of muscle and cardiovascular health. Vitamin D also plays a role in immune health and many other systems in the body.

In people deficient in vitamin D, long-term effects are bone softening, known as osteomalacia in adults and rickets in children (who can also suffer bone deformities). Other symptoms can be vague but can include bone pain and muscle weakness, joint pain (particularly of the wrists, ankles, shoulders, and shins), chronic tension headaches, depression, insomnia and hair loss (Khan, J Oncol Pract 2010). Vitamin D deficiency has also been linked with a greater risk of blood in the urine in postmenopausal, but not premenopausal women (Ryu, BMC Nephrol 2019). However, this association does not prove cause-and-effect, and it is unknown if vitamin D supplementation reduces blood in the urine. In infants, a common early symptom of deficiency can be excessive sweating (Hossein-nezhad, Mayo Clin Proc 2013).

Vitamin D deficiency is also linked to increased risk of depression, cognitive decline and Alzheimer's disease, heart attack, and mortality, although getting *too much* vitamin D may also increase some of these risks (see How Much Is Too Much).

Bone and fractures

Vitamin D regulates the amount of calcium and phosphorus in the body, partly by controlling their levels of absorption. Vitamin D treats and prevents **rickets** in children and **osteomalacia** (bone softening) in adults. However, as discussed below, benefits of vitamin D supplementation on bone appear generally limited to people deficient in vitamin D, i.e., having blood levels below 20 ng/mL and, even then, some studies have not shown a benefit.

A study of 81 vitamin D trials went so far as to conclude that "vitamin D supplementation does not prevent fractures or falls, or have clinically meaningful effects on bone mineral density" — although this study did not analyze results according to the vitamin D status of trial participants and the study authors acknowledged that "trials in individuals with marked vitamin D deficiency...might produce different results." (Bolland, Lancet Diab & Endocrin 2018).

In adults:

One of the largest vitamin D studies in the U.S. (VITAL) concluded that vitamin D taken daily by adults (ages 50+) for about 5.3 years did *not* result in a significantly lower risk of **fractures** than placebo; however, calcium supplementation was not given as part of the study, relatively few of the participants began the study deficient in vitamin D (the average blood level at the start of the study was 30.7 ng/mL) and the dose given was high (2,000 IU, or 50 mcg) raising average levels to over 40 ng/mL. Nevertheless, exploratory analyses among those with starting levels below 12 ng/mL or below 20 ng/mL, as well as those taking calcium on their own, did not show lower risk of fractures with vitamin D than placebo (LeBoff, NEJM 2022).

Although not all studies have shown a benefit of vitamin D supplementation in reducing fractures, a review of several studies concluded that supplementation with 800 IU or more of vitamin D was "somewhat favorable" in the prevention of hip fracture and any nonvertebral fracture in people 65 years of age or older (Bischoff-Ferrari, N Engl J Med 2012). Most notably, it found a 30% reduction in hip fracture among people taking 792 to 2,000 IU of vitamin D per day compared to those taking no vitamin D or small amounts (up to 360 IU per day). The review also suggested that vitamin D blood levels above 24 ng/mL are most beneficial for reducing the risk of both hip and nonvertebral fractures, and frequent dosing of vitamin D (such as daily or weekly) is more beneficial than annual dosing. Similarly, a large study of men aged 70 to 97 years in Sydney, Australia found that those with vitamin D levels between 24 and 29 ng/mL were least likely to suffer bone fractures. In comparison to this group, men with lower levels (at or below 14.4 ng/mL) and higher levels (above 29.2 ng/mL) were, respectively, 3.5 and 2.7 times as likely to experience a fracture — suggesting a potential risk from too little, as well as too much, vitamin D in the body (Bleicher, J Bone and Min Res 2014).

A large, long-term study that followed 68,132 postmenopausal women (age 50 to 79) for 20 years, who on average, were getting 370 IU of vitamin D (less than the recommended 600 to 800 IU for this age group) from food and supplements, found that taking 200 IU of vitamin D3 and 500 mg of calcium (from calcium carbonate) twice daily for seven years reduced the risk of **hip fracture** by 23% compared to those receiving placebo, although it did *not* decrease the risk of lower arm or wrist fracture (Manson, JAMA 2024). An earlier analysis of the same study found that when the calcium/vitamin D supplement was given to women receiving hormonal therapy (after hysterectomy), the risk of hip fracture was reduced by half compared to placebo (Robbins, Menopause 2013).

Taken with calcium, vitamin D may also **decrease postmenopausal bone loss and prevent osteoporosis** (loss of bone density), as well as improve **tooth retention** in the elderly. *However, if a person's blood level of vitamin D is already close to or above 20 ng/mL, taking a vitamin D supplement provides no further bone benefit.* This was demonstrated in a placebo-controlled study of a group of white, postmenopausal women in New York with an average vitamin D level above 20 ng/mL (but below 30 ng/mL). Taking 4,000 IU of vitamin D_3 daily for 6 months did not reduce bone loss in these women (based on measurements of bone turnover markers which occur in the blood) (Aloia, J Clin Endocrin Metab 2013). In the same study, some of the women were given high-dose calcium supplementation (1,200 mg from calcium carbonate, as 600 mg twice a day). Those who received the calcium showed signs of reduced bone loss during the study -- regardless of whether they received the vitamin D supplement. This benefit is likely due to the fact that the women, on average, were not getting the recommended daily intake of calcium before supplementation (their average intake was 900 mg, while the recommended daily intake for women their age is 1,200 mg). It is possible that a lower dose of calcium would also have been beneficial, as well as safer: Too much calcium from supplements has been associated with a higher risk of kidney stones and stroke (see Calcium Review -- Concerns and Cautions).

In a study among older women (average age 67) with blood levels of vitamin D averaging 19 ng/mL, daily doses of vitamin D ranging from 400 IU to 4,800 IU were not associated with a significant effect on bone mineral density compared to placebo. During the study, all of the women maintained a total calcium intake of 1,200 mg per day from food and/or calcium supplements (Smith, J Intern Med 2018). (Another analysis of the same study, discussed in the Muscle, Balance and Falls section below, found that the rate of falls was lowest in women who achieved vitamin D blood levels of 32-38 ng/mL after supplementation — but women with higher blood levels had the highest rate of falls.)

Another placebo-controlled study in postmenopausal women compared the effectiveness of 800 IU of vitamin D_3 daily (400 IU twice a day) to the same daily dose plus an additional 20,000 IU twice a week. Both groups also received 1,000 mg of calcium daily (500 mg twice a day from calcium carbonate). After one year, bone mineral density was unchanged or slightly improved in both groups. Markers of bone turnover (bone loss) in blood serum were also reduced in both groups, but the *higher dose was actually less efficient at reducing bone turnover*, contrary to what the researchers had expected (Grimnes, Osteoporos Int 2012).

Similarly, a study of postmenopausal women in Wisconsin found no beneficial effect on bone mineral density from giving vitamin D at low-dose (800 IU daily) or high-dose (800 IU daily plus 50,000 IU twice monthly) for 1 year, compared to placebo. There was also no beneficial effect on muscle function, muscle mass, or falls, and only a small effect on calcium absorption. Women in the study started with a median vitamin D blood level of 21 ng/mL and, during the study, averaged 19, 28, and 56 ng/mL, respectively, in the placebo, low-, and high-dose groups. The women in this study had adequate calcium intake. The researchers concluded that the findings did not support "experts' recommendations" to maintain levels of 30 ng/mL or higher in postmenopausal women, but did support the Institute of Medicine's recommended level of at least 20 ng/mL (Hansen, JAMA 2015).

A study in the U.S. among 687 older men and women (average age 63) with sufficient blood levels of vitamin D, most of whom had some degree of bone loss, showed that taking 2,000 IU of vitamin D3 daily for two years did not increase bone mineral density or improve bone structure compared to placebo. Supplementation increased average blood levels of vitamin D from 27 ng/mL to 39 ng/mL. Calcium intakes were not reported, but 17% of the participants reported using a calcium supplement and, among these, there was less bone mineral density loss in the neck of the femur if they were taking vitamin D versus placebo but there was no benefit in whole body bone mineral density (LeBoff, J Bone Miner Res 2020).

Middle-aged and older women who follow a **vegan** diet and do not supplement with calcium and vitamin D were found to have *three times the risk* of **hip fracture** compared to women who are not vegetarians, while women who follow a vegan diet but take supplemental calcium and vitamin D did not have an increased risk, according to a large study of men and women ages 42 and older. No association between calcium and vitamin D supplementation and hip fracture risk was found in men who follow a vegan diet (Thorpe, Am J Clin Nutr 2021). (See the Calcium Supplements Review for more details.)

Be aware that vitamin D deficiency may impede **healing from fractures**, as was reported in a 44-year-old man in the Netherlands whose femoral (thighbone) fracture failed to heal four years after the initial injury despite multiple surgeries to properly set the bone. He was found to have severe vitamin D deficiency (25(OH)D of 4 ng/mL) and diagnosed with hyperparathyroidism due to vitamin D deficiency and low dietary calcium intake. He was given weekly injections of 50,000 IU of vitamin D for six weeks, after which he took 400 IU of oral vitamin D and 500 mg of calcium daily. Eight months after supplementation began, his vitamin D levels were sufficient (24 ng/mL) and his fracture healed (Moone, Nutrition 2021).

In healing fractures, improving one's vitamin D level alone is insufficient if calcium intake is inadequate, as shown in a study in the Netherlands of 32 postmenopausal women (average age 65) with wrist fractures who had low levels of vitamin D (average 25(OH)D of 17 ng/mL) and inadequate intake of calcium (average 715 mg per day, compared to the 1,200 mg per day recommended for women in this age group). They were divided into three groups and given one oral dose of either 30,000 IU or 75,000 IU of vitamin D, which was repeated six weeks later, or no vitamin supplementation. None of the groups received calcium supplementation. Despite increasing their levels to 20 ng/mL and 23 ng/mL, respectively, their fractures healed no better than those in women who did not receive vitamin D. In fact, the higher dose of vitamin D (equivalent to 1,800 IU per day) resulted in *poorer* bone healing than in the control group. (As noted elsewhere in this Review, large single doses of vitamin D have been shown to be detrimental.) There were no differences in self-reported pain or function between the lower and higher dose groups or the control group (Heyer, J Bone Miner Res 2021).

Vitamin D may reduce **aging of bones**. Compared to bone samples from the hips of people with vitamin D blood levels of 20 ng/mL or higher, bone from those with levels below 20 ng/mL (i.e., deficient in vitamin D) were found to be more brittle (over-mineralized) on the inside while thicker and under-mineralized on the outside. When physically tested, bone from vitamin D-deficient people was 22% more likely to crack and the cracks were longer compared to bone from people not deficient in vitamin D. The researchers believe that osteoclast cells, which normally keep bone healthy, cannot get through the thick, under-mineralized outer layer of bone formed in vitamin D-deficient people and, as a result, areas of bone under this layer continue to age and over-mineralize even as the overall bone mineral content progressively decreases (Busse, Sci Transl Med 2013).

No association between blood levels of vitamin D (or use of vitamin D supplements) and **low back pain** were found in a study in the UK that followed 135,934 participants for average of 8.5 years (Sha, Nutrients 2024). A much smaller study among 232 postmenopausal women in China found that vitamin D levels below 10 ng/mL (severe deficiency) were associated with more severe **lumbosacral disc degeneration** and low back pain among compared levels of 30 ng/mL and higher, but there was no significant difference in disc degeneration between the groups, leading the researchers to speculate that only extremely low vitamin D levels might affect disc degeneration (Xu, Menopause 2020).

In children:

Although vitamin D supplementation is recommended for **breast-fed infants** to prevent vitamin D deficiency, *it does not appear to increase **bone density***. Despite conflicting evidence from an early study showing increased bone mineralization among infants receiving vitamin D supplementation compared to those receiving placebo (Greer, J Pediatr 1981), numerous subsequent studies have not found supplementation to increase bone mineral content, bone density or improve markers of bone metabolism in breast-fed infants through 12 months of age (Ziegler, J Clin Nutr Metab 2017; Gallo, JAMA 2013; Kim, J Korean Med Sci 2010; Greer, J Pediatr 1989). For example, a study in Taiwan among 72 infants who were exclusively breast-fed found that, by 4 months of age, those supplemented with 400 IU of vitamin D daily since 10 days of age had higher blood levels of vitamin D compared to those receiving placebo (38.6 vs. 13.6 ng/mL), but there was no increase in bone mineral content or bone mineral density, although those infants with severe vitamin D deficiency (< 10 ng/mL) at the end of the study (likely due to low levels to start and being in the placebo group) had lower bone mineral content than those *without* severe vitamin D deficiency (at least 10 ng/mL) (2.7 vs. 2.9 grams) (Lin, ASBMR 2022). Although the specific reason for this lack of benefit is unclear, experts speculate that vitamin D may have limited effect on bone mineralization provided intake of other minerals (especially calcium) is adequate (Ziegler, J Clin Nutr Metab 2017; Gallo, JAMA 2013).

In girls ages 9 to 13, regular supplementation with calcium and vitamin D has been shown to significantly increase bone density and bone strength (measured in arms and legs) compared to placebo (Greene, Osteoporosis Int 2011). Similarly, in girls ages 10 to 17, supplementation with vitamin D for one year significantly improved bone mineral density in their hips. This effect was not seen among boys of the same age (Al-Shaar, Bone 2013). It is notable, however, that 83% of the girls and 80% of the boys in this study in Lebanon were deficient in vitamin D (below 20 ng/mL) to start. In fact, 34% of the girls started with levels below 10 ng/mL. Two different doses of vitamin D_3 were used in the study, a low dose (1,400 IU) or a high dose (14,000 IU), each given weekly. Interestingly, greater improvements were seen with the lower dose, although the differences were not statistically significant.

One study suggests that children whose mothers supplement with high-dose vitamin D during pregnancy may have a reduced risk of **tooth enamel defects** (but not dental carries, i.e., cavities) (see the Pregnancy section for details).

Periodontal disease

Because vitamin D plays a role in bone health and immunity, there has been some speculation that vitamin D deficiency may contribute to periodontal disease (infections and inflammation of the gums and bone surrounding the teeth) and that correcting deficiency may improve this condition, although evidence from observational research has been mixed (Bhargava, J Oral Biol Craniofac Res 2019; Bonnet, JCDA 2019; Lee, Int J Environ Res Public Health 2021).

Nevertheless, in a report of severe periodontitis that did not respond adequately to non-surgical periodontal therapy (i.e., scaling and root planning) in a 40-year-old woman with a low vitamin D level (25(OH)D of 15.2 ng/mL), increasing the woman's vitamin D levels prior to administering subsequent periodontal treatment allowed the dentists to correct the patient's periodontitis. The authors stated that, "vitamin D deficiency should be suspected, investigated, and eventually treated, in the case of periodontal situations that do not improve after conventional treatment" (Mario, Case Rep Dent 2022).

Interestingly, a study in India among 88 young adults (average age 30) with **gingivitis** (gum inflammation) and adequate levels of vitamin D (average levels: 22.47 to 28.81 ng/mL) showed that taking 500 IU of vitamin D daily for 90 days increased average blood levels of vitamin D by 12.83 ng/mL (to 36.81 ng/mL) and reduced gingival inflammation by 1.36 points (on a scale of 0 to 3) compared to placebo. Taking 1,000, or 2,000 IU of vitamin D daily reduced gingival inflammation sooner, but the researchers concluded that raising levels to 30 to 35 ng/mL seemed to be optimal and could be achieved with 500 IU daily (Srivastava, J Pharm Bioallied Sci 2023).

Strength and muscle function

Vitamin D receptors are found on skeletal muscle, and these receptors are involved in protein synthesis within the muscle. However, as described below, the benefits of vitamin D supplementation on muscle strength and function, if any, appear to be limited to only those with very low levels and older individuals.

In older adults:

Supplementation with moderate doses of vitamin D (800 to 1,000 IU or 20 to 25 mcg daily) may improve muscle mass and strength in older adults with very low levels of vitamin D. Vitamin D supplementation does not appear to be beneficial among older adults who already have adequate levels of vitamin D, and higher doses may have adverse effects on muscle strength.

A 9-month study in younger postmenopausal Brazilian women (ages 50 to 65) known to be deficient in vitamin D (averaging 15 ng/mL) and with a history of falls found that a daily dose of 1,000 IU (25 mcg), given as liquid drops, increased the average level to 27.5 ng/mL and was associated with a 25.3% **increase in muscle strength of the lower limbs**, as demonstrated by chair rising test, but no increase in handgrip strength. Although there was no exercise component of the study, women receiving the vitamin D maintained lean mass (muscle) while women in the placebo group lost lean mass (Cangussu, Osteoporos Int 2015). Similarly, giving 800 IU (20 mcg) of vitamin D daily to postmenopausal women in Turkey who were deficient in vitamin D (average level of 10 ng/mL) resulted in small but statistically significant increases in muscle strength in the hamstring and quadriceps. In contrast, women in the study who were, instead, given a single, very high dose (300,000 IU or 750 mcg) of vitamin D did *not* have a statistically significant improvement despite a greater rise in their vitamin D levels even through the end of the 12 week study (Apaydin, BMC Endocr Disor 2018).

Vitamin D supplementation — 2,000 to 4,000 IU (50 to 100 mcg) daily or 20,000 IU (500 mcg) twice weekly for up to 12 months — **does *not* appear to improve muscle strength or power among older adults who already have sufficient levels** (at least 20 ng/mL) (Bischoff-Ferrari, Osteoporos Int 2025; Grimnes, Clin Endocrinol (Oxf) 2017) or those with slightly lower levels (18.5 to 19.6 ng/mL) (Houston, Am J Clin Nutr 2023; Ceglia, J Clin Endocrin Metab 2013).

Too high a dose of vitamin D may actually *weaken* leg muscles or reduce physical activity, even among people with low levels of vitamin D.

For example, in a study of women with hyperparathyroidism and low vitamin D levels (average 12.4 ng/mL), taking 2,800 IU (70 mcg) of vitamin D3 daily for 3 months *reduced* maximal handgrip strength by 9%, knee flexion strength by 13%, and *slowed physical movement (rising from a chair)* compared to placebo (Bislev, Calcif Tissue Int 2018). This was attributed to a "direct detrimental effect" of moderately high-dose vitamin D, as those taking vitamin D developed increased blood levels of several compounds associated with muscle breakdown compared to placebo (Bislev, Nutrients 2020). Among postmenopausal women with low but adequate vitamin D levels at baseline (21.4 ng/mL), taking 2,000 IU (50 mcg) per day of vitamin D significantly *decreased* leg strength (-2.5 pounds decrease in lifting weight vs. +1.8 pounds increase with placebo) and had no benefit on weight loss (see Weight control) (Mason, JAGS 2016).

Similarly, among healthy, active older men and women (average age 75) with adequate levels of vitamin D (average: 22.4 ng/mL), taking 2,000 IU (50 mcg) per day of vitamin D3 daily for 3 years did *not* improve strength or muscle function and modestly *reduced* self-reported physical activity compared to those not receiving vitamin D (Hussein, J Nutr Health Aging 2025).

A study among 100 men and women (average age 71) with blood levels of vitamin D at the lower end of adequate (22.8 ng/mL) showed that supplementing with low-dose (800 IU or 20 mcg daily) or high-dose (50,000 IU or 1,250 mcg monthly, which is equivalent to about 1,667 IU or 42 mcg daily) vitamin D for 17 weeks, 10 of which included twice weekly resistance training, did *not* significantly improve measures of strength (including 30-second chair stand, arm curl, timed up and go, or 6-minute walk tests) compared to those receiving placebo + resistance training, despite modestly increasing blood levels of vitamin D, respectively, to 25.8 and 32.9 ng/mL versus no change in vitamin D levels in the placebo group. Furthermore, those in the high monthly dose group showed a significant **increase in markers of DNA damage that have been linked with increased cancer risk** compared to those in the lower, daily-dose group. Interestingly, those in the placebo group also showed increased evidence of DNA damage, suggesting that resistance training itself might contribute to this adverse effect, but more DNA damage occurred among those in the high-dose group (Draxler, Redox Biol 2023).

In younger adults:

Despite earlier evidence suggesting a possible benefit of vitamin D for improving strength in younger adults (Tomlinson, J Sci and Med in Sport 2015), more recent studies suggest that vitamin D supplementation does not improve strength, muscle function, or physical performance in younger adults, even those with low levels of vitamin D.

No increase in muscle strength occurred in a placebo-controlled study of slightly older, active adults (average age 44) in Japan, although lean body mass (i.e., muscle) increased by 1 lb. Participants were initially deficient in vitamin D and were given 420 IU (10.5 mcg) of vitamin D3 daily, raising blood levels from an average of 13 ng/mL to 24 ng/mL (Sun, Ann Nutr Metab 2019).

A study in Estonia among 39 previously untrained men (average age 23) with low blood levels of vitamin D (averaging 14 ng/mL as 25(OH)D) who began a strength training program (3 sessions per week, supplementing with 20 grams of whey protein after each session) showed that taking 8,000 IU (200 mcg) of vitamin D3 daily for three months did *not* increase training-induced gains in muscle strength or lean body mass compared to strength training plus placebo, despite raising average blood levels to 57 ng/mL 25(OH)D. In fact, men who took the placebo (and had low blood levels of vitamin D throughout training) had greater gains in muscle strength in two of the seven strength exercises performed (chest press and seated row) compared to those who took vitamin D. The researchers suggested that benefits might only occur in people with severe deficiency (< 10 ng/mL) and the very high dose vitamin D given may actually *block* the activity of vitamin D receptors (as pointed out by other researchers) (Savolainen, Eur J Appl Physiol 2021).

A study in China among 117 healthy university students (average age 19) showed that supplementing with 1,000 IU of vitamin D daily for one month during the winter significantly increased blood levels of vitamin D from 18.85 to 26.98 ng/mL and reduced the percentage of participants with vitamin D deficiency from 64.3% to 8.9% but did *not* significantly improve measures of physical performance, including vertical jump height, right handgrip strength, or lung function, compared to placebo (Zhang, J Int Soc Sports Nutr 2023).

Balance and falls

Supplementation with moderate doses of vitamin D to correct insufficient levels may improve balance and decrease the risk of falls in older adults with low blood levels of vitamin D. High doses may increase fall risk among older adults.

One of the best studies of vitamin D and falls focused on **women with insufficient levels of vitamin D** (blood levels less than 20 ng/mL) who had not taken vitamin D supplements and were getting only about 120 IU daily of vitamin D from their diets. They were divided into groups given 400 IU, 800 IU, 1,600 IU, 3,200 IU, 4,000 IU, or 4,800 IU of vitamin D3 or a placebo. Over the course of one year, 58% of those given the placebo had fallen, but those given 1,600 to 3,200 IU of vitamin D3 had the lowest rate of falls — just 30%. Those given lower or higher doses did not fall significantly less than the placebo group. Women ending with blood levels of 32 to 38 ng/mL had the lowest rate of falls (21%), while the highest rate of falls (72%) was among those with levels of 38 to 46 ng/mL. *In short, those who received enough vitamin D to correct insufficiencies but remained under about 40 ng/mL fared best* (Smith, J Steroid Biochem Mol Biol 2017). On the other hand, high monthly doses (60,000 per month — equivalent to 2,000 IU per day, which increased vitamin D blood levels to 40.1 ng/mL — or 24,000 IU monthly along with 300 mcg of calcifediol — a more potent vitamin D metabolite — which increased blood levels to 44.2 ng/mL) appear to *increase* the risk of falls and fracture among older adults, the majority of whom had low levels of vitamin D at baseline (<20 ng/mL) (Bischoff-Ferrari, JAMA Intern Med 2016).

Vitamin D does *not* appear to reduce fall risk among **older adults with adequate blood levels** (Aloia, J Am Geriatr Soc 2019; USPSTF, JAMA 2018; Grimnes, Clin Endocrinol (Oxf) 2017; Uusi-Rasi, JAMA Intern Med 2015) and, similar to the effect among people with insufficient levels, high-dose supplementation may actually *increase* the risk. A study among older men and women (average age 77) with elevated fall risk and low but adequate levels of vitamin D (22 ng/mL) found an 87% *increased* risk of a serious fall (resulting in fracture or dislocation), 166% *increased* risk of first-time fall resulting in a fracture, and 148% *increased* risk of a fall requiring hospitalization among those who received 1,000, 2,000 or 4,000 IU of vitamin D daily (which increased blood levels to 32, 35 and 48 ng/mL) compared to those who took just 200 IU per day (which increased blood levels to 27 ng/mL) (Appel, Ann Intern Med 2020; Wanigatunga, J Am Geriatr Soc 2021). Similarly, a study among community-dwelling older women at high risk of fracture but with nearly adequate levels of vitamin D at baseline (19.6 ng/mL) found that annual high-dose vitamin D (500,000 IU per year) *increased* the incidence of falls by 31% compared to placebo during the first three months after supplementation, when blood levels of vitamin D were increased to 36 to 48 ng/mL for those in the supplement group (Sanders, JAMA 2010; Dawson-Hughes, JAMA 2010). A study among older men and women, the majority of whom had adequate levels of vitamin D at baseline, showed that normal-weight participants given high dose vitamin D supplementation (60,000 IU monthly, which is equivalent to about 2,000 IU daily) had a 25% *increased* risk of falls compared to those who were overweight. The researchers speculated that people with less body fat (where vitamin can be stored) may have higher circulating levels of vitamin D when taking high doses compared to those with more body fat (Waterhouse, J Cachexia Sarcopenia Muscle 2021).

Orthostatic intolerance (OI)

Orthostatic intolerance, which can cause dizziness or fainting upon standing, includes conditions such as orthostatic hypotension, vasovagal syndrome, and postural tachycardia syndrome (POTS).

Although vitamin D deficiency in men has been linked with an increased risk of **orthostatic hypotension (low blood pressure when standing)**, a type of orthostatic intolerance that is associated with an increased risk of falls and fractures (Gilani, Age Ageing 2020; Mol, J Am Med Dir Assoc 2019; Hamrefors, PloS One 2016), giving vitamin D (1,000, 2,000, or 4,000 IU daily) to older adults with orthostatic

hypotension and vitamin D levels ranging from 10 to 29 ng/mL does *not* appear to help reduce orthostatic symptoms (such as lightheadedness, dizziness, seeing spots, imbalance, headache, etc.) compared to taking 200 IU of vitamin D3 daily (Juraschek, Circulation 2021).

On the other hand, a small study among teenage girls (average age 16) with OI and vitamin D levels averaging 22 ng/mL (i.e., at the lower end of adequate) found that taking 2,000 to 5,000 IU of vitamin D daily for two months increased vitamin D levels to 41 ng/mL, on average, and increased the amount of time the girls could tolerate standing on head-up tilt by about 15 minutes. Heart rate variability when standing on tilt was also increased after vitamin D treatment, which suggests the body was under less stress. Baroreflex sensitivity, a measure of how well the heart rate adapts to changes in blood pressure, also improved after supplementation with vitamin D. However, the study did not include a control group, so it's not possible to conclude that vitamin D supplementation improves OI (Shaltout, Hypertension 2020).

Vertigo — Benign Paroxysmal Positional Vertigo (BPPV)

BPPV is a common form of vertigo that is caused by displacement of calcium carbonate crystals (otoliths) within the inner ear. The condition appears to be more common during months when vitamin D levels are low (Meghi, Otol Neurotol 2017). Several studies suggest that *taking a vitamin D supplement may reduce the risk of episodes of vertigo in people with BPPV, although it has not been shown to improve balance or decrease the risk of falls. Studies to-date have focused on people with low or borderline levels of vitamin D (20 ng/mL and lower).*.

A study in South Korea among 34 men and women with low vitamin D blood levels (average 13 ng/mL) who had been successfully treated with a repositioning maneuver for a recent episode of BPPV found that those given 7,000 IU (175 mcg) of vitamin D once weekly for one year after the treatment were significantly less likely to experience another vertigo episode compared to those who took a placebo. Among those who took vitamin D, average blood levels of vitamin D increased to 29 ng/mL and only 2 participants (9.5%) experienced another episode within the year compared to 6 participants (44.4%) in the placebo group, whose blood levels of vitamin D remained low (14 ng/mL) (Kong, Laryngoscope Investig Otolaryngol 2024).

Similar benefits were shown in an even larger study of 957 people in South Korea recently treated (with a repositioning maneuver) for BPPV. In the study, people in the intervention group were evaluated for serum levels of vitamin D at baseline, and those with levels less than 20 ng/mL were given 400 IU of vitamin D and 500 mg of calcium carbonate twice daily for 12 months. People in the observation group were not evaluated for vitamin D status and not given supplementation. Both groups were followed for about one year, although data was considered for any person who had been followed up for at least one month. People in the intervention group had a 24% lower rate of BPPV recurrence compared to those in the observation group, with greatest benefit seen for patients in the treatment group who had been vitamin D deficient (25-hydroxyvitamin D levels <10 ng/mL) (Jeong, Neurology 2020). A smaller, earlier study showed similar benefit (Matos Carniero de Sousa, Hear Bal Comm 2019).

In people with BBPV with borderline levels of vitamin D (averaging 20 ng/mL), taking vitamin D was shown to reduce the recurrence of BPPV and the time between episodes (De Chua, Otolaryngol Head Neck Surg 2024), but it did *not* significantly improve balance or decrease falls compared to placebo (Huang, Aging Clin Exp Res 2025).

Overactive bladder and urinary incontinence

Low blood levels of vitamin D have been associated with higher risk of **overactive bladder (OAB)** (i.e., suffering from urinary urgency or frequency with or without incontinence) (Yoo, BJU Int 2018), possibly explained by the role of vitamin D in muscle function (Parker-Autry, Int Urogynecol J 2012). However, it is unclear if vitamin D supplementation improves urinary symptoms, even in people with low levels of vitamin D.

A small study in Jordan, for example, found that people with severe vitamin D deficiency (below 10 ng/mL) were *32 times more likely* to have overactive bladder symptoms than people with levels above 30 ng/mL. No rigorous studies have been conducted to determine if vitamin D is beneficial in OAB, but the same Jordanian researchers gave vitamin D (50,000 IU weekly for 4 to 8 weeks) with encouragement to increase dietary calcium intake to 13 people with OAB (11 of whom had vitamin D levels below 20 ng/mL) in whom

drug therapies had not been successful. The vast majority of these patients reported improvements in nighttime and daytime urinary symptoms, although it is impossible to evaluate the clinical significance of these results as there was no placebo or other scientific control (Abdul-Razzak, Neurourology and Urodynamic, 2019).

Symptoms in women

A study among 56 women (average age 60) with **urgency urinary incontinence** found that, overall, vitamin D supplementation (50,000 IU weekly for three months) *did not* improve bladder symptoms, pelvic floor muscle function, or functional status compared to placebo, although it should be noted that most of the women who took vitamin D had sufficient blood levels before supplementation. A sub-group analysis found a significant decrease in the number of incontinence episodes per day among Black women who took vitamin D compared to placebo (-63% vs. -22%). During the study, average blood levels of vitamin D increased from 21 ng/mL to 58 ng/mL among those who took vitamin D (Markland, J Am Geriatr Soc 2019).

Symptoms in men

A preliminary study in South Korea among 57 men (average age 64) with insufficient blood levels of vitamin D (average 16 ng/mL) and moderate **lower urinary tract symptoms (LUTS)** (such as urinary frequency, urgency, and nighttime urination) showed that, among those who took 25,000 IU (625 mcg) of vitamin D3 every 2 weeks for one year, average blood levels of vitamin D increased to 30 ng/mL and there was a significant decrease in the amount of urine in the bladder after urination but only a slight reduction in LUTS symptoms, which was not deemed clinically meaningful. There was no change in prostate volume or PSA (prostate-specific antigen) levels. Among men in a control group who did not take vitamin D, there was no improvement in urinary symptoms and a modest increase in prostate volume. However, the researchers did not report if the improvements in the vitamin D group were statistically significant compared to the control group and there was no placebo-control, which is needed to prove a benefit, limiting the significance of the findings (Yeo, World J Mens Health 2023).

Statin drugs and vitamin D

If you use a statin medication for cholesterol-lowering, it may be helpful to maintain sufficient blood levels of vitamin D for the following reasons:

Statins may work better when vitamin D is adequate:

A 6-month, placebo-controlled study in China among people with high cholesterol and treated with statin drugs found that taking 2,000 IU of vitamin D_3 tablets significantly improved cholesterol levels. Approximately half the people in the study began with vitamin D blood levels below 20 ng/mL (i.e., vitamin D deficient) and about another quarter had levels between 20 and 30 ng/mL. Mean vitamin D blood levels increased by 17.1 ng/mL in the treated group and by 2.4 ng/mL in the placebo group (due to increased sun exposure because the study ended in June). Compared to the placebo group, which experienced slight improvements in cholesterol levels, total cholesterol levels in the treated group fell by an additional 22.1 ng/mL, triglycerides fell by 28.2 mg/dL, LDL ("bad") cholesterol fell by 20.2 mg/dL, and HDL ("good") cholesterol increased by 8.2 mg/dL. Improvements were greater when excluding those who began the study with vitamin D levels of 30 ng/mL or higher (no analysis was reported of just those who had been vitamin D deficient). The researchers noted that these results with vitamin D may be limited to statin-treated patients (Qin, Clin Nutr 2015).

Note — Giving high-dose vitamin D to people who are *not* deficient may slightly *increase* cholesterol levels (see Concerns and Cautions).

Statin-related decline in exercise performance is blunted when vitamin D is adequate:

While statins can lessen improvements in cardiorespiratory fitness that normally occur with exercise as well as reduce the content of mitochondria (i.e., the "energy powerhouses") in muscle cells, vitamin D adequacy may lessen these negative effects. A study in India among 28 people with type 2 diabetes who were vitamin D deficient (averaging about 10 ng/mL) found that, after 12 weeks of performing moderate aerobic exercise, those given simvastatin (40 mg daily) had an 8.4% decrease in cardiovascular fitness, but if also given vitamin D (60,000 IU weekly — which is a very high dose), the decrease was only 0.6%. Skeletal muscle mitochondrial content decreased 3.6% with simvastatin but improved 12.1% if vitamin D was also given. Vitamin D alone, without simvastatin, increased cardiovascular fitness and mitochondrial content by 7.1% and 16.7%, respectively (Singla, J Diabetes 2017).

More vitamin D is needed to raise blood levels when taking a statin:

A review of clinical trials in which vitamin D was given to people aged 60 and over with low vitamin D levels found that statin users had a 21.4% smaller increase in vitamin D blood levels than people not using statins (Bischoff-Ferrari, JAGS 2017). It would seem advisable to use a slightly higher than normal dose of vitamin D if you are taking a statin.

Vitamin D levels may increase or decrease depending on the statin:

In small clinical trials, certain statin medications have been shown to increase blood levels of vitamin D, while other stains have been shown to have little effect or to slightly decrease blood levels of vitamin D — possibly due to enzymes involved in metabolizing these drugs or whether the drugs are more soluble in fats or water.

- **Rosuvastatin (Crestor)** was shown to increase 25(OH)D levels by 22.3 ng/mL and 1,25-dihydroxyvitamin D (the active form) by 3.7 pg/dL when taken daily for 8 weeks (Yavuz, Cardiovasc Drugs Ther 2009), although not all studies have found a large an impact. This was also seen in a separate study by the same research group in which rosuvastatin (10 mg/day) taken daily for two months increased 25(OH)D blood levels by about 23 ng/mL (from 11.8 to 35.2 ng/mL); however, the same study found that **fluvastatin (Lescol XL)**, taken at a dose of 80 mg per day, had *no effect* on vitamin D levels (Ertugrul, Cardiovasc Ther 2011).

- **Atorvastatin (Lipitor)** appears to have a more modest effect on vitamin D levels, although results from clinical trials have been inconsistent. A study in Spain found that either a low (10 mg to 20 mg) or higher (40 mg to 80 mg) daily doses of atorvastatin for one year led to modest increases in 25(OH)D blood levels (about 3 ng/mL) (Perez-Castrillon, Am J Cardiol 2007). However, a study in India found that atorvastatin (10 mg/day) taken for six months caused a small but significant reduction in 25(OH)D blood levels (about 2 ng/mL), while those taking rosuvastatin (5 mg/day) showed an increase in 25(OH)D levels, although the increase was modest (about 2 ng/mL) compared to the studies described above. The researchers noted that atorvastatin is a stronger inducer (i.e. it enhances activity) of an enzyme (CYP3A4) involved in the breakdown of 25(OH)D, possibly explaining the reduction (Patwardhan, Indian J Pharmacol 2020).

- There is some evidence that 20 to 80 mg of **lovastatin (Mevacor)** daily increases 25(OH)D blood levels, while it seems that **simvastatin (Zocor)** either increases or has little effect on vitamin D levels (Gupta, Atherosclerosis 2011).

However, vitamin D does not seem to prevent or reverse existing statin-related muscle pain.

A large, randomized, controlled trial among 2,083 men and women (average age 67) who began statin therapy and were followed for about 5 years found that daily supplementation with high-dose vitamin D (2,000 IU — i.e., 50 mcg — per day) did *not* decrease the occurrence statin-related muscle symptoms or prevent statin discontinuation compared to placebo, even among those who began the study with blood levels of vitamin D of less than 20 ng/mL (Hlatky, JAMA Cardiol 2022).

A study among 38 people (average age 51) with adequate levels of vitamin D (>20 ng/mL) showed that discontinuing long-term statin use for 2 months, then supplementing with 30,000 IU of vitamin D weekly for one month before reinitiating statin treatment did *not* reduce the risk of experiencing statin-related muscle symptoms compared to placebo when reinitiating statin therapy (Peyrel, J Clin Lipidol 2023).

Keep in mind that severe *vitamin D deficiency itself — regardless of statin use — can cause bone pain and muscle weakness*. This can be reversed with vitamin D. This may explain why a preliminary study found that giving vitamin D to 42 people with low levels of vitamin D (averaging 15 ng/mL) who also had muscle pain with statin therapy (which was scaled back or ended) reduced pain intensity by an average of 63% and improved walking ability, mood, and sleep, while there were no improvements in a similar group of people not given vitamin D. There was no placebo-control group, however, as needed to *prove* a benefit. Vitamin D was taken as 25,000 IU (625 mcg) once weekly for six months. After 3 months, some of the participants were able to tolerate high dose statin therapy (Carallo, Metab Syndr Relat Disord 2022).

Back pain

A study among overweight and obese adults in Australia with back pain who also were deficient in vitamin D (levels below 20 ng/mL) found that high-dose vitamin D significantly reduced back pain among those who were *severely deficient* (levels below 12 ng/mL), but not among those with levels above 12 ng/mL. Vitamin D was given as an initial 100,000 IU dose followed by 4,000 IU per day for 16 weeks, boosting levels, on average, by 22 ng/mL (Brady, J Ster Biochem Mol Biol 2018). [Note: Obese individuals require larger doses of vitamin D to raise levels.]

Rheumatoid arthritis

*Low levels of vitamin D are associated with a higher risk of developing **rheumatoid arthritis** and may be associated with more significant disease severity and progression. There is also evidence that taking vitamin D modestly reduces the risk of developing rheumatoid arthritis.*

A study in China found the mean level of serum vitamin D in men and women with rheumatoid arthritis to be 17.2 ng/mL, while it was 23.2 ng/mL in a matched control group of individuals without rheumatoid arthritis. Among the patients with arthritis, lower vitamin D levels were associated with higher rates of swollen joint, tender joint, joint pain, and morning stiffness, as well as osteopenia and osteoporosis (Hong Rheumatology 2014). Similarly, a study in France among 643 people with early rheumatoid arthritis found that disease activity and severity was worse at baseline for those with vitamin D deficiency (<10 ng/mL) compared to those with higher levels. Vitamin D deficiency was also associated with a 70% greater chance of functional disability at 6 months, as well as 90% greater chance of radiographic progression and erosion progression at 12 months (Mouterde, J Rheumatol 2020).

A large, multi-year study (the VITAL trial) of older individuals (average age of 67) across the U.S. found that taking 2,000 IU of vitamin D daily reduced the risk of developing autoimmune disease by 22% compared to taking placebo — although the absolute reduction was small — 32 fewer confirmed cases out of about 13,000 people. Adding fish oil had no effect. People with lower body mass index (BMI) seemed to benefit much more than those with higher BMI. Although risk reductions in specific autoimmune diseases were not statistically significant, an apparent reduction was most notable for rheumatoid arthritis (42% reduction), while there was an apparent 64% *increase* in risk of thyroid disease i.e., Grave's and Hashimoto's disease (also, as discussed below, vitamin supplementation has not been shown to be beneficial in people with hyperthyroidism due to Grave's disease). Interestingly, few (13%) participants began the study deficient in vitamin D (< 20 ng/mL), with the average starting level of 30.7 ng/mL, which rose by about 12 ng/mL in the first year. Other analyses of this study found no reductions in heart disease, cancer, or deaths from those diseases with vitamin D (Hahn, BMJ 2022).

Osteoarthritis (worn joints)

Overall, studies suggest that vitamin D supplementation does not appear to benefit osteoarthritis of the knee in people with adequate blood levels of vitamin D. There is mixed evidence as to whether it may help those who are deficient in vitamin D.

Giving vitamin D_3 to people with painful osteoarthritis of the knee was *not* found to improve symptoms nor slow progression of the disease more than giving a placebo, according to a two-year study in Boston (McAlindon, JAMA 2013). In fact, throughout the study, those given vitamin D were more likely to report using non-steroidal anti-inflammatory drugs (e.g., ibuprofen) than patients given placebo. However, most patients who participated in the study were *not deficient* in vitamin D to begin with -- the average starting blood level of 22.7 ng/mL. Vitamin D was given at an initial dose of 2,000 IU daily and then adjusted, primarily upward, to achieve levels over 36 ng/mL. Only the subset of people who began the study deficient in vitamin D (levels below 15 ng/mL) experienced improvement taking vitamin D, although this improvement could not be considered statistically significant due to the small size of this group.

Similarly, a large three-year study among people aged 50 years and older in the UK with knee osteoarthritis given 800 IU daily of vitamin D3 showed no benefit compared to placebo with regard to progressive narrowing of the joint space, mobility, function, or pain. The average starting blood level of vitamin D was just slightly above 20 ng/mL, with half the individuals under that amount and, therefore, deficient in vitamin D. However, unlike the study above, further analysis did not show better results for those who started the study deficient in vitamin D compared to those who were not (Arden, Osteoarth Cartilge 2016).

A two-year study in Australia found that vitamin D supplementation (50,000 IU per month: equal to 1,667 IU per day) did *not* reduce **knee pain** or prevent the **loss of knee cartilage** volume compared to placebo, despite increasing average blood levels of vitamin D from 17.5 ng/mL to 24 ng/mL Although not an original endpoint of the study, there was a statistically significant improvement in joint function for the vitamin D group compared to placebo (Jin, JAMA, 2016). A follow-up analysis showed that, overall, there was no improvement in knee pain or function among those who took vitamin D compared to placebo three years after the study ended. However, among **participants who had not undergone knee surgery**, there was modest improvement in knee function with vitamin D compared placebo, and significantly less knee pain and dysfunction among those who maintained an adequate blood level of vitamin D (20 ng/mL or more) compared to those who did not (Wang, Arthritis Res Ther 2023). A further analysis of the study results suggested that the effects of taking vitamin D depended on participants starting blood levels of vitamin D: Among those with vitamin D deficiency at baseline (25(OH)D: 5 to 17 ng/mL), supplementing with vitamin D for two years improved joint pain/stiffness and knee function by about 256 points (out of 500 points) compared to only about 72 points in the placebo group, although there was *no reduction* in cartilage volume loss or progression of cartilage defects. In contrast, there was no reduction in knee pain or improvement in knee function among those who started with vitamin D blood levels of 17 to 24 ng/mL, although they did have *slightly* less loss of cartilage and slightly less progression of cartilage defects (by about 0.66 on a scale of 0 to 39) compared to placebo (Wang, Rheumap 2025).

An analysis of data from the Jin study that looked at the effects of vitamin D supplementation on **foot pain and related disability**, which is common in people with knee osteoarthritis and associated with more severe knee pain, found modest improvements in foot pain and disability in the vitamin D treatment group that maintained blood levels of 20 to 30 ng/mL. Although small, these improvements were, statistically, significantly better than the general lack of improvement seen in the placebo group as well as in those in the treatment group who did not maintain blood levels of at least 20 ng/mL (Tu, Arthritis Care Res (Hoboken) 2020).

Cardiovascular disease, blood pressure, and cholesterol

As discussed below, several studies have shown increased risk of cardiovascular disease associated with lower blood levels of vitamin D (i.e., lower than 15 to 20 ng/mL). Studies in which vitamin D has been given to people with low levels have shown cardiovascular benefits (e.g., small improvements in blood pressure, cholesterol, arterial stiffness) with regular, moderate doses (600 to 1,000 IU), but generally less benefit and even side effects with higher doses (2,000 IU daily or 100,000 IU monthly or quarterly). There appears to be no cardiovascular benefit giving high-dose vitamin D to people with blood levels already above 15 to 20 ng/mL.

A major study (the VITAL study) of a cross-section of older Americans given 2,000 IU of vitamin D daily for a median of 5.3 years found no overall reduction in cardiovascular events (heart attack, stroke, or death from cardiovascular causes) relative to placebo. However, participants were *not deficient in vitamin D* — the average starting blood level was 30.8 ng/mL, which increased to over 40 ng/mL among those given vitamin D during the study (Manson, NEJM 2018).

Similarly, a study in England gave 2,000 or 4,000 IU of vitamin D, or a placebo, daily for one year to over 300 generally healthy older people with average vitamin D blood levels of 20 ng/mL -- about 10% of whom were already taking 400 IU of vitamin D or more daily. Although blood levels of vitamin D more than doubled, there was no significant effect on blood pressure, heart rate, arterial stiffness, echocardiogram measures, cardiac function, or blood levels of prohormone that regulates blood pressure (Tomson, J Am Heart Assoc 2017).

On the other hand, an earlier analysis of two large studies showed that men who consumed 600 IU or more per day of vitamin D from foods and supplements were 16% less likely to have **cardiovascular disease and stroke** over a period of approximately 20 years compared to men consuming less than 100 IU per day. The same association was not seen among women; the reason for this is unclear but one possible explanation given is that women may need higher intake of vitamin D because they tend to have a higher percentage of body fat than men and vitamin D is fat soluble. In addition, vitamin D intake during the study period, which ended in 2006, may have been too low to produce meaningful differences (Sun, Am J Clin Nutr 2011).

Research has found that men with low levels of vitamin D in the blood (15 ng/mL and lower) are at increased risk for **heart attack** compared to those with levels at 30 ng/mL and higher, even after adjusting for other risk factors and physical activity. Similarly, in a study lasting about 6 years, adults with vitamin D levels below 30 ng/mL were more likely like to suffer from **hypertension**, **coronary**

artery disease, **cardiomyopathy**, and **diabetes** than those with higher levels (Vacek, Prev Cardio 2012). In fact, after adjusting for other factors, the **risk of death** from all causes was 164% higher among those with the lower levels of vitamin D. The researchers note that 71% of people in the study (involving over 10,000 people in Kansas) had serum vitamin D levels below 30 ng/mL — the mean was 24.1 ng/mL. Among those with levels below 30 ng/mL, the risk of death was reduced if a vitamin D supplement was being taken; however, there was no such additional advantage with supplementation for those with levels already above 30 ng/mL. The researchers did not analyze the results by further subgroups of vitamin D level. A study that followed 230,000 men and women (average age 48) in the southwest U.S. for 5 years applied different vitamin D level subgroupings and found that the risk of cardiovascular disease was 35% higher for those with vitamin D levels below 15 ng/mL (9% of the studied population) compared to those with higher levels (Muhlestein, Circulation 2015). Although the apparent benefit of avoiding vitamin D deficiency appears dramatic, there is potential downside from much higher levels (see How Much Do You Need and "How Much is Too Much?" for more about mortality rates and vitamin D).

In **people with chronic heart failure**, research suggests that long-term, high-dose vitamin D supplementation does *not* improve mortality rates or most measures of heart function and may *worsen* certain outcomes.

In a study in the UK, 163 people with chronic heart failure (less than half the normal ventricular output) were given high-dose (4,000 IU) vitamin D_3 or placebo daily for 1 year, with the primary goal of increasing walking distance in a 6-minute test. All patients started the study with vitamin D levels below 20 ng/mL. Among those given vitamin D, blood levels of vitamin D generally rose to about 50 ng/mL, however, there was no increase in walking distance -- which actually *decreased by 4%*, while it increased by 4% among those given placebo. Those taking vitamin D did experience a modest but statistically greater improvement in heart output (left ventricular ejection fraction increased from 25.6% at baseline to 33.3%, while, in the placebo group, it increased from 26.5% at baseline to only 27.9%) (Witte, J Am Coll Cardiol 2016). [ConsumerLab.com Comment: The high dose given in this study caused patients to achieve unusually high vitamin D blood levels -- levels associated with *increased falls* in other studies, possibly explaining the reduction in walking distance despite improved heart output. A lower but still higher than normal dose (e.g., 2,000 IU) could have achieved vitamin D sufficiency and may have improved heart output *as well as* improved walking distance.]

A similar study in South Korea among 73 people with chronic heart failure (≤40% normal ventricular output) and low levels of vitamin D (averaging only 12.6 ng/mL) showed that supplementing with 4,000 IU (100 mcg) of vitamin D daily for 6 months increased blood levels of vitamin D to 51.5 ng/mL, but there were no statistically significant changes in blood pressure, heart rate, 6-minute walking distance, measures of endothelial function or heart remodeling (including heart output and chamber size), or self-reported pain, anxiety, mobility, or ability to perform usual daily activities compared to the placebo group (Woo, Medicine 2022).

A placebo-controlled study in Germany among 400 people with advanced heart failure and low blood levels of vitamin D found that 4,000 IU of vitamin D given daily for three years increased median blood levels of 25(OH)D from 14 ng/mL to 37 ng/mL but did not reduce mortality and *increased* the need for mechanical circulatory support (MCS) implants (used to manage reduced heart output) and hospitalization (Zittermann, Eur Heart J 2017). Researchers followed the participants for an additional three years after supplementation ended (during which blood levels of vitamin D would have likely decreased) and found that those previously treated with vitamin D were no longer at increased risk of requiring an MCS implant or hospitalization, further suggesting that high-dose supplementation had a detrimental effect (Zittermann, ESC Heart Failure 2020).

Low levels of vitamin D are generally associated with **elevated blood pressure**. However, studies have, *at best*, shown only a modest reduction in blood pressure when vitamin D is given. A comprehensive review of 46 trials concluded that vitamin D is ineffective for lowering blood pressure, regardless of starting levels of vitamin D in the blood, and should not be used as antihypertensive agent -- although most patients with hypertension in the analyzed studies were also being treated with antihypertensive medication, possibly obscuring an effect of vitamin D (Beveridge, JAMA Intern Med 2015). One trial that found no effect was conducted among adults ages 70 and older with systolic hypertension. The participants, most of whom were also taking anti-hypertension medication, were given 100,000 IU of vitamin D3 every three months (equaling 1,100 IU per day) for one year, raising the mean vitamin D blood level from 18 ng/mL to 28 ng/mL. Vitamin D supplementation failed to improve hypertension or other measures of cardiovascular health, including cholesterol levels (Witham, JAMA 2013). However, another placebo-controlled study using a dose of 2,000 IU of vitamin D3 daily for 6 months found that those receiving vitamin D supplementation experienced reductions in systolic and diastolic blood pressures of,

respectively, 6.2 mm Hg and 4.2 mm Hg compared to those given placebo. People in the study were all taking nifedipine (a calcium channel blocker). Among those receiving vitamin D, mean vitamin D blood levels rose from 19.4 ng/mL to 34.1 ng/mL (Chen, Atherosclerosis 2014).

Be aware that one study found vitamin D deficiency to be associated with *low blood pressure* upon standing (known as orthostatic hypotension) in older men (see Muscle, balance and falls for details).

A 12-week study in Iran of overweight and obese premenopausal women found that daily supplementation for 12 weeks with 1,000 IU vitamin D3 increased HDL ("good") **cholesterol** by 7%. However, total cholesterol increased 1.7% and there was also a 4% increase in LDL ("bad") cholesterol — although it contained less ApoB, suggesting less plaque-forming ability. Interestingly, **body fat** decreased by 9.6% (about 6 lbs), although total body weight was unchanged (Salehpour, Br J Nutr 2012). A larger and longer (2 year) study in the U.S. found that postmenopausal women given 400 IU of vitamin D3 and 1,000 mg of calcium (from calcium carbonate), taken in two divided doses daily, experienced a 4.5 mg/dL decrease in LDL cholesterol compared to those who received a placebo. Vitamin D blood levels rose to a mean of 24.3 ng/mL among the supplemented women compared to 18.2 ng/mL in the placebo group. Although there was no statistically significant effect of taking the supplement on total cholesterol, HDL, or triglycerides, the researchers did find that women with higher blood levels of vitamin D tended to have higher levels of HDL and lower levels of both triglycerides and LDL (Schnatz, Menopause 2014).

A small study of obese adolescents given a monthly dose of 100,000 IU of vitamin D3 for 3 months (averaging 3,333 IU per day) showed no improvement in arterial function and insulin and glucose levels, and increases of 32% and 9%, respectively, in triglycerides and total cholesterol. A weakness of the study was that few participants had been deficient in vitamin D (below 20 ng/mL), with the average starting level of 22 ng/mL, which increased to 35 ng/mL (Javed, Pediatric Obesity 2015). A large placebo-controlled study giving 100,000 IU of vitamin D3 monthly to older adults (average age of 66), for approximately 3 years found no reduction in cardiovascular events even among a subgroup who started the study deficient in vitamin D (blood levels below 20 ng/mL) (Scragg, JAMA Cardio 2017). However, a 16-week study among overweight African-Americans with vitamin D deficiency (blood levels averaging about 15 ng/mL), found that high doses of vitamin D (60,000 IU or 120,000 IU given once-a-month -- each of which raised levels to about 35 ng/mL) improved (i.e., reduced) arterial stiffness by about 8 to 10%. A lower dose (18,000 IU per month) did not have this effect despite raising the levels to an average to 23 ng/mL. The study did not assess effects on cardiovascular disease (Raed, PLOSOne 2017).

Diabetes, insulin resistance and glucose control

Maintaining a vitamin D level of at least 25 or 26 ng/mL or moderately higher may reduce insulin resistance and may improve blood sugar control in people at risk for or with diabetes, although not all studies have found a benefit. There is preliminary evidence that vitamin D supplementation may modestly reduce the pain of peripheral neuropathy in people with type 2 diabetes who have low blood levels of vitamin D.

Risk of type 1 diabetes

Higher serum levels of vitamin D — up to a point -- have been associated with a lower risk of developing **type 1 diabetes** (i.e., requiring insulin). In a study of two thousand people on active duty in the military, those with vitamin D levels between 24 and 31 ng/mL had the lowest risk of being diagnosed with type 1 diabetes. Compared to this group, the risk of diabetes was more than 2.5 times as great among those with levels between 17 and 24 ng/mL, and the risk was more than 3.5 times as great among those with levels below 17 ng/mL. No risk reduction was associated with levels above 31 ng/mL — in fact, the risk of diabetes was slightly higher for those with levels above 31 ng/mL than those with levels between 24 and 31 ng/mL (Gorham, Diabetologia 2012).

Observational data suggests that dietary intake of vitamin D is associated with lower risk of developing type 1 diabetes (Hypponen, Lancet 2001). It has been suggested that to reduce the risk of type 1 diabetes, infants and children receive supplemental vitamin D if they have limited sun exposure, live in northern areas, are exclusively breastfed, or are dark skinned (Harris, J Nutr 2005).

Insulin resistance and prediabetes

Obesity itself is a major risk factor for insulin resistance, but too little vitamin D may increase the risk. A study found that obese individuals with vitamin D blood levels below 20 ng/mL were 12 times more likely to be insulin resistant than obese individuals with sufficient levels of vitamin D (Kabadi, Diabetes Care 2012) . In addition, a study of overweight and obese women who were not diabetic found that vitamin D blood levels of at least 26 ng/mL appear to be needed for normal glucose metabolism in both Black and white women, and those with this amount of vitamin D had lower body fat, blood glucose, insulin and triglyceride levels than women with lower levels of vitamin D (Sorkin, JN 2014).

Furthermore, a study of 115 overweight older adults in Lebanon with low average blood levels of vitamin D (10 ng/mL) but who did not have diabetes (although 14 were considered to be pre-diabetic) found that 10,000 IU of vitamin D3 taken three times per week for six months modestly reduced insulin resistance (as measured by HOMA-IR) from an average of 2.63 to 2.4, and decreased fasting blood sugar levels, compared to placebo (Hajj, J Nutr Health Aging 2018). However, a placebo-controlled trial among 64 men and women in Ireland with prediabetes and low blood levels of vitamin D found that high-dose vitamin D (3,000 IU daily for six months) *did not* improve blood sugar control or insulin function despite increasing vitamin D blood levels from an average of 12 ng/mL to 40 ng/mL (Wallace, Am J Clin Nutr 2019).

Maintaining adequate blood levels of vitamin D may have a beneficial effect on blood sugar and insulin levels in healthy people who are not overweight: A study among 81 healthy men and women in Japan, most of whom had low or deficient blood levels of vitamin D (average blood level 13 ng/mL) found that, compared to placebo, 420 IU of vitamin D3 taken daily for one year increased average blood levels of vitamin D to an average of 24 ng/mL, decreased fasting blood glucose (from an average of 88.3 mg/dL to 85.3 mg/dL), and improved insulin resistance values (as measured by HOMA-IR) from 1.17 to 0.84 (Sun, Nutr Res 2016).

Risk of type 2 diabetes

Observational research has suggested a link between adequate blood levels of vitamin D and reduced risk of developing type 2 diabetes (Mitri, Eur J Clin Nutr 2011). A study in India among men and women with **prediabetes and very low blood levels of vitamin D** (averaging 10 ng/mL) found that oral supplementation with 60,000 IU of vitamin D3 after breakfast once a week (equivalent to about 2,140 IU daily) for three months improved insulin sensitivity (measured by the insulin sensitivity (OGIS) index) compared to placebo. However, there were no improvements in the insulin-sensitivity check index (QUICKI), HOMA-IR, nor in fasting or post-meal blood sugar levels compared to placebo. Interestingly, average vitamin D blood levels in those who took vitamin D increased to 52 ng/mL, which is above the level at which the risk of adverse effects may increase (Ahmed, Cureus 2020).

There is conflicting evidence about whether supplementing **people at risk of type 2 diabetes who have adequate blood levels of vitamin D** improves blood sugar control or reduces the incidence of type 2 diabetes. A placebo-controlled study among overweight older men and women at high risk of diabetes or newly diagnosed type 2 diabetes with vitamin D levels averaging 21 ng/mL (45% of whom were below 20 ng/mL, i.e., vitamin D insufficient) found that supplementation for 6 months with 5,000 IU daily of vitamin D significantly improved peripheral (i.e., in muscles) insulin sensitivity although not hepatic sensitivity, i.e., there was no improvement in insulin secretion, glucose levels, or HbA1C (Lemieux, Eur J Endocrin 2019).

A large, placebo-controlled, 2.5-year study in which people with prediabetes and adequate blood levels of vitamin D took 4,000 IU of vitamin D daily, raising the average blood level of vitamin D from 27.7 ng/mL to 54.3 ng/mL, showed no reduction in the risk of developing type 2 diabetes. However, among the subgroup of people who started the study with vitamin D levels below 12 ng/mL, those given vitamin D were 62% *less likely* to develop type 2 diabetes than those given placebo — a major difference. Furthermore, when only participants who adhered to the study protocol were considered, supplementation with vitamin D reduced the risk of diabetes by 16% compared to placebo (Pittas, NEJM 2019) and were 31% to 45% more likely to achieve normal blood sugar regulation compared to those in the placebo group. However, these benefits were only seen with 2.5 years of compliance and not at 2 years (Hsia, Diabetes Res Clin Pract 2023).

On the other hand, taking 2,000 IU of vitamin D daily for about 5 ½ years did *not* reduce the risk of developing type 2 diabetes, compared to placebo, in the VITAL study among the more than 22,000 healthy older Americans (average age 67) most of whom had adequate blood levels of vitamin D to start. This lack of benefit persisted even among the subgroup of participants with lower blood levels of

vitamin D at baseline (<20 ng/mL) (Tobias, Nat Commun 2025).

In people with type 2 diabetes

Among people with type 2 diabetes with vitamin D levels of 20 ng/mL or higher, vitamin D supplementation may not provide benefit (Mitri, Eur J Clin Nutr 2011). In fact, a large U.S.-based trial found that giving high-dose vitamin D (4,000 IU daily) for 48 weeks to people with stable type 2 diabetes who were not vitamin D deficient (average starting level was 27 ng/mL) did not improve any measure of blood sugar control (Angellotti, J Endocrine Society 2018). Also see "Depression" below for more about type 2 diabetes and vitamin D.)

A study in Indonesia among 68 men and women (average age 65) with type 2 diabetes and low 25(OH)D levels of vitamin D (average 15 ng/mL) who also had **peripheral neuropathy** (nerve damage resulting in pain, numbness, burning, tingling and other sensations in the hands and feet) found that 125 mcg (5,000 IU) of vitamin D taken daily for eight weeks in addition to standard treatment (pregabalin, gabapentin, or amitriptyline) *modestly* reduced self-reported *overall pain* scores (- 3.34 vs -2.37 points on a 10-point scale) compared to standard treatment alone. However, both groups experienced similar reductions in burning pain (an average reduction of about 10 points on a 100-point scale), and vitamin D did not reduce tingling, electric shock pain or numbness and did not improve sleep quality, general activity scores, or mood compared to standard treatment alone. Blood levels increased to an average of 40 ng/mL among those given vitamin D but remained low (18 ng/mL) in the others (Pinzon, J Pain Res 2021). More research is needed to confirm any benefit, as the study did not include a placebo control.

A study in Denmark found that both high and low vitamin D levels are associated with a form of nerve damage called **cardiovascular autonomic neuropathy (CAN)** in people with type 1 and type 2 diabetes. CAN affects heart rate and blood vessel function and may cause low blood pressure on standing and exercise intolerance. Patients with CAN have a greater chance of having a heart attack and lower chance of surviving one. The findings suggest that beneficial effects of vitamin D are restricted to a specific serum range (around 20 ng/mL to 50 ng/mL) and both too low and too high levels are detrimental to the autonomic nervous system (Hansen, Diabetic Med 2016).This may help explain similar associations found between vitamin D levels and falls as well as mortality.

Gestational diabetes

Supplementation with a combination vitamin D and calcium may improve blood sugar control in pregnant women with **gestational diabetes**. In a six-week study of 56 women with gestational diabetes (at 24 to 28 weeks gestation), those who received 1,000 mg calcium per day, plus 50,000 IU of vitamin D3 at the beginning of the study and another 50,000 IU at week 3, had significantly lower fasting blood glucose levels compared to those given placebo (respectively, a 0.89 mmol/l reduction versus a 0.26 mmol/L increase), lower serum insulin levels (-13.55 vs. +9.17 pmol/L), and a significant increase in insulin sensitivity (+0.02 vs -0.002) (Asemi, Diabetologia 2014).

Non-alcoholic fatty liver disease (NAFLD):

Low levels of vitamin D have been associated with non-alcoholic fatty liver disease -- the accumulation of fat in the liver (also called hepatic steatosis) which can lead to inflammation, scarring and cirrhosis (Elaides, Aliment Pharmacol Ther 2013). NAFLD affects approximately 30% of Americans. A preliminary study in 40 women and men with significant liver fat accumulation and insufficient blood levels of vitamin D (averaging 11.8 ng/mL) found that with a weekly dose of 20,000 IU of vitamin D3 (equivalent to about 2,857 IU per day), liver fattiness decreased by approximately 5% after only four weeks; while vitamin levels rose to an average of about 35 ng/mL. A weakness of this study, however, is that it did not include a control group (Papaostoli, J Gastrointestin Liver Dis 2016). A study of adults with NAFLD with vitamin D blood levels below 30 ng/mL given 2,000 IU of vitamin D daily for six months found that levels rose above 30 ng/mL in most (75%) of those who did not have liver inflammation but in only 15% of those with inflammation (known as steatohepatitis). Only those whose levels increased showed significant improvements in plasma ALT levels (an indicator of liver function) and HOMA-IR scores (an assessment of insulin resistance). Higher doses of vitamin D may be necessary to sufficiently raise vitamin D levels in such people (Dasarathy, J of Nutr 2017).

Inflammation

Raising low levels of vitamin D may also reduce inflammation in the body. In a study of blood from thousands of adult Americans, levels of C-reactive protein (CRP), a marker of inflammation, decreased as vitamin D levels increased to just below 21 ng/mL 28 (Am J Cardiol 2012). However, there was no further benefit when vitamin D levels reached and exceeded 21 ng/mL. In fact, after adjusting for cardiovascular risk factors, it was found that CRP levels slowly but progressively *increased* at that point, *suggesting a slight inflammatory action of vitamin D* at these higher levels. The results seem to reinforce the importance of maintaining a plasma vitamin D level of at least 20 ng/mL and suggest some potential downside of higher levels of vitamin D.

Somewhat similar conclusions were drawn from a well-controlled, 1-year study of vitamin D in adults aged 60 to 84 years in Australia. Starting with vitamin D levels of about 17 ng/mL, people were given monthly dose of vitamin D of 30,000 IU (equal to 1,000 IU/day), 60,000 IU, or a placebo. At 1 year, there were no significant differences in levels of inflammatory biomarkers in the treated groups versus placebo — except for a slight increase in a pro-inflammatory marker (IL-6) in the higher-dosed group, half of whom achieved vitamin D blood levels of 30 ng/mL or higher. The researchers note that this may suggest a detrimental effect of higher vitamin D levels (Waterhouse, Br J Nutr 2015).

Vitamin D appears to accelerate the resolution of inflammatory responses during **tuberculosis** therapy (Coussens, PNAS 2012). In a study in London, patients given very large doses of vitamin D3 (100,000 IU every 2 weeks) along with standard antibiotic therapy had less inflammation, and their infections cleared 13 days earlier on average, than patients who did not receive vitamin D. It is important to note, however, the very high prevalence of profound vitamin D deficiency in the studied population -- more than half the patients had levels of vitamin D below 8 ng/mL prior to therapy. Added vitamin D may not yield the same benefits for patients who already have sufficient levels of vitamin D.

Asthma

Moderate doses of vitamin D may improve symptoms of asthma in children as well as in adults with uncontrolled asthma. Prenatal supplementation with vitamin D may also reduce the risk of asthma in offspring. However, improvements seem to be limited to those with very low vitamin D levels, e.g. less than 10 ng/mL.

A review of medical studies published from 1950 to 2009 that looked at, among other variables, vitamin D intake and asthma, suggested that vitamin D deficiency may be linked to airway inflammation, decreased lung function and poor asthma control. The researchers conducting the review hypothesized that vitamin D supplementation may lead to improved asthma control, although this cannot be established as many of the studies were not specifically designed to test the effects of vitamin D supplementation on patients with asthma (Urashima, Am J Clin Nutr 2010). A clinical study published in 2014 tested whether high-dose vitamin D supplementation reduced treatment failures among adults with asthma already receiving an inhaled corticosteroid (ciclesonide) and a bronchodilator (levalbuterol). Vitamin D supplementation (4,000 IU per day after an initial 100,000 IU dose) did *not* lead to a statistically significant reduction in initial treatment failures compared to those receiving a placebo supplement. However, during the 28-week study, the group receiving vitamin D was 20% less likely to have a treatment failure and 37% less likely to have an exacerbation of symptoms. It is possible that more significant results may have been obtained if the study did not have certain weaknesses: Half the patients started the study with vitamin D levels above 20 ng/mL and, therefore, were not vitamin D deficient and might not benefit from additional vitamin D; and, because of the very high dosage used in the study, many of these people may have achieved unusually high blood levels of vitamin D which other studies suggest may counter beneficial effects of vitamin D (Castro, JAMA 2014). A small pilot study (not placebo-controlled) tested a lower dose (a daily capsule of 2,000 IU of vitamin D3) for 12 weeks in asthmatic people ages 65 and older in Philadelphia. Prior to initiation of therapy, it found that mean vitamin D levels in the blood were significantly lower (19.0 ng/mL) in those with uncontrolled asthma compared to those with well-controlled symptoms (25.7 ng/mL). Self-reported symptoms of asthma decreased significantly after 12 weeks of vitamin D treatment only in patients who had uncontrolled asthma, although clinical measurements of airflow remained unchanged. The researchers note that vitamin D receptors are present in the smooth muscle of the bronchi and vitamin D has been shown to play a role in modulating the immune system (Columbo, Allergy, Asthma, & Clin Immun 2014).

A small study in the U.K. among 27 adults (average age 38) with mild to moderate asthma and low levels of vitamin D (14.7 ng/mL) showed that supplementing with high dose vitamin D (5,000 IU or 125 mcg daily) for 12 weeks during the winter (when the body produces less vitamin D from sunlight) *slightly* improved lung function by 4.6% compared to only 0.6% in the placebo group. However, there were no significant improvements in asthma symptoms (such as shortness of breath, need for reliever medication, and how often symptoms interrupted sleep) or markers of inflammation compared to placebo. As it was winter, blood levels of vitamin D in the placebo group decreased (from 14.4 to 7.9 ng/mL) and levels in the vitamin D group only increased moderately (from 14.7 to 19.2 ng/mL) — with an ending level still slightly below what is considered adequate (Watkins, Br J Nutr 2024).

A study in Japan among schoolchildren with asthma found that giving them each 800 IU of vitamin D daily for two months led to significantly greater improvements in asthma control than did giving a placebo. This improvement remained significant even four months after discontinuing vitamin D, at which point 34% of those who had received placebo had difficulty breathing compared to only 15% of those who had received vitamin D. Interestingly, the children in both groups had had relatively high levels of vitamin D (around 30 ng/mL) before the trial began and few were vitamin D deficient (Tachimoto, Allergy 2016). In contrast, a placebo-controlled study among 192 children with asthma in the U.S. aged 6 to 16 years (most of whom had vitamin D levels above 20 ng/mL) found that giving very high-dose vitamin D (4,000 IU daily) for 48 weeks did not reduce the number of days until the next severe asthma exacerbation or lead to reductions in their use of an inhaled steroid (fluticasone) (Forno, JAMA 2020). Furthermore, analysis of additional data from the study showed that supplementing with vitamin D did not reduce the immune response (based on antibody levels) to dust mites or cockroaches — two common triggers of year-round asthma attacks (Rosser, J Allergy Clin Immunol 2021).

A review in 2016 of seven clinical trials (ranging in length from 4 months to one year -- including the Castro and Tachimoto studies noted above) investigating the effects of vitamin D supplementation in children or adults with asthma (most of whom had mild to moderate asthma and used their regular asthma medications as needed) found that oral vitamin D supplementation (average daily dose 900 IU vitamin D3, although some participants received additional, larger doses in some trials) reduced the average number of attacks per year requiring treatment with oral steroid medication from 0.44 to 0.22, and reduced the risk of hospitalization from asthma attacks from 6% to about 3%. However, measures of lung function (such as forced expiratory volume, or FEV1) were not improved (Martineau, Cochrane Database Syst Rev 2016). Due to lack of data, the researchers were not able to assess whether the improvements would be limited to those who were deficient in vitamin D before supplementation, or whether those with more severe asthma would benefit. A later review of studies similarly found that vitamin D supplementation reduces the rates of asthma exacerbations requiring treatment with systemic corticosteroids. *However*, it found that these protective effects were only seen among people with very low vitamin D levels (less than 10 ng/mL) prior to vitamin D treatment and not in people with higher levels (Jolliffee, Lancet Respir Med, 2017).

Prenatal supplementation with vitamin D may **reduce the risk of asthma and recurrent wheeze** in offspring by the age of 6 years, although the benefit may be limited to only mothers who were vitamin D deficient and/or when supplementation was started *before* the second trimester. A study in the U.S. in which 806 pregnant women (about 13% of whom were vitamin D deficient and another 26% to 30% who had low levels) who were given 4,400 IU of vitamin D3 or placebo (i.e., 400 IU of vitamin D, which is below the recommended daily allowance of 600 IU per day during pregnancy) daily starting at 10 to 18 weeks gestation and continued until delivery showed that the odds of the child developing asthma or recurrent wheeze in the first six years of life was 74% lower among the subgroup of women who were deficient and received intervention compared to those who were deficient and received placebo. There was no reduction in risk with vitamin D supplementation among women with low or adequate levels compared to placebo. Interestingly, the odds of asthma or recurrent wheeze in the child by the age of six was 55% lower among the women who initiated vitamin D supplementation *before the second trimester* (i.e., by 12 weeks gestation or earlier) compared to the placebo group, but there was no significant reduction in risk among women who initiated supplementation in the second trimester (Shadid, Am J Clin Nutr 2023).

COPD (Chronic obstructive pulmonary disease)

Several studies have shown that high-dose vitamin D may reduce exacerbations in adults with COPD and/or asthma who also have low blood levels of vitamin D, but it does not appear to be beneficial in those who already have sufficient levels.

A placebo-controlled study in the UK of 240 people with COPD found that taking vitamin D3 (120,000 IU orally every 2 months — equal to 2,000 IU per day) significantly reduced the risk of having moderate or severe exacerbations among those who began the study deficient in vitamin D (blood levels below 20 ng/mL). This benefit was not found for those who began the study with sufficient levels of vitamin D. Vitamin D did not reduce the risk of upper respiratory infection among any group (Martineau, Lancet Resp Med 2014).

A study in Belgium found that vitamin D supplementation (100,000 IU every 4 weeks) significantly reduced exacerbations of COPD but only among patients starting with vitamin D levels less than 10 ng/mL (Lehouck, Ann Intern Med 2012). Similarly, a study in New Zealand among 775 older men and women (average age 67) with **asthma and/or COPD** found that, overall, vitamin D3 supplementation (initial oral dose of 200,000 IU followed by 100,000 IU monthly for more than three years) did not reduce the risk of exacerbations (use of oral corticosteroids more than 20 days) compared to placebo, except in those who began the study with deficient blood levels of vitamin D (< 10 ng/mL) (Camargo, Nutrients 2021).

Allergies

Higher serum vitamin D levels are associated with a reduced risk of allergy in children and adolescents, but not in adults. Preliminary evidence suggests that supplementing people with low levels of vitamin D may help reduce some symptoms of allergy, and giving vitamin D to pregnant women may reduce infants' risk of allergic sensitivity.

A review of data from a nationwide study of over 6,000 individuals showed that, for children and adolescents, allergic sensitization was more common in those with serum vitamin D of less than 15 ng/mL compared to those with 30 ng/mL or greater for 11 out of 17 allergens. Results were adjusted for potentially confounding factors like time spent on indoor activities. The strongest associations were for allergy to oak (5 times the risk), peanut (2.4 times the risk), and ragweed (1.8 times the risk). There was also increased risk of allergy to dog, cockroach, mite, shrimp, ryegrass, Bermuda grass, birch and thistle. In adults, there was no consistent association between allergy and vitamin D levels(Sharief, J Allergy Clin Immunol, 2011).

Giving vitamin D daily to infants (as well as to their mothers while pregnant) *reduces infants' risk of allergic sensitivity to dust mites* and *reduces visits to the doctor for **asthma** during infancy*. This was shown in a study in New Zealand in which pregnant women were given 1,000 IU or 2,000 IU of vitamin D during the last 3 months of pregnancy and their newborn infants were then given, respectively, 400 IU or 800 IU for 6 months. Another group of mothers and infants received placebo. During the first 18 months of life, 11% of infants in the placebo group saw a doctor for asthma, compared to 0% who received the lower dose of vitamin D and 4% who received the higher dose. Virtually all of the infants were breastfed at birth, although 47% began infant formula prior to age six months. The researchers noted that other studies have shown that sensitization to dust mites is associated with increased risk of childhood asthma (Grant, Allergy 2016).

A double-blind study among 68 men and women (average age 29) in Iran with seasonal allergies (allergic rhinitis) with generally low average blood levels of vitamin D (14.4 ng/mL) found that those who took 50,000 IU of vitamin D3 once per week for two months in addition to the antihistamine medication cetirizine (Zyrtec, Aller-Tec) had significant decreases in self-reported nasal itching, sneezing, runny nose and post-nasal drip compared to those who took cetirizine with a placebo. There was no improvement in eye redness and itching. Among those who took vitamin D, average blood levels of vitamin D increased to 24 ng/mL while levels remained relatively unchanged (15 ng/mL) in those who did not take vitamin D (Bakhshaee, Eur Arch Otorhinolaryngol 2019). Similarly, a study in India among 600 adults with seasonal allergies, about 32% of whom had low levels of vitamin D (25(OH)D < 20 ng/mL), showed that taking 60,000 IU of vitamin D weekly for 2 months, followed by monthly doses for 4 months, along with the antihistamine fluticasone furoate (Flonase), significantly reduced the severity of nasal symptoms (-8.8 vs -3.2 points on a scale of 0 to 15) and IgE levels (-64% vs -46%) compared to those receiving only the antihistamine. Those who discontinued vitamin D supplementation after the first two months but continued using the antihistamine showed a rebound of nasal symptoms (Rana, Indian J Otolaryngol Head Neck Surg 2025).

Dry eye

A study among 116 men and women with moderate **dry eye disease** found that those who took one capsule daily containing lutein (20 mg), zeaxanthin isomers (4 mg), curcumin (200 mg curcuminoids), and vitamin D3 (600 IU or 15 mcg) (*Blink NutriTears* sold by Bausch + Lomb) in the morning with or after a meal for 8 weeks had a 67% increase in tear production versus only 3% with placebo and a 57% reduction in the severity of dry eye symptoms such as pain, grittiness, and sensitivity to light, versus only 13% with placebo. However, despite the improvements, supplementation did *not* increase the rate of tear production to within normal ranges or decrease the need for artificial tears compared to placebo. The study was funded by Bausch + Lomb and OmniActive Health Technologies (which manufacturers the supplement) which employ some of the study authors (Gioa, Front Ophthalmol 2024). Be aware that, although there is some preliminary evidence that curcumin may be helpful for dry eye, a worsening of dry eye with curcumin supplementation has also been reported by one CL member. (Also see our article about supplements for dry eye.)

Chronic hives (urticaria)

Chronic hives, or urticaria, is characterized by the recurring appearance of hives and welts. A 12-week, placebo-controlled study among 120 people with chronic urticaria in India who were deficient in vitamin D (average blood level of 14 ng/mL) found that a 60,000 IU dose of vitamin D3 taken every two weeks (averaging 4,286 IU per day) significantly reduced disease severity and levels of inflammatory cytokines in the blood. The need for antihistamine medication also decreased. Blood levels of vitamin D increased to an average 29.5 ng/mL among those taking it. The researchers attribute the improvement to vitamin D's action as an immunoregulatory hormone (Mony, Clinica Chimica Acta, 2020). [Note, it is preferable to take lower doses of vitamin D daily or weekly than a large dose less often, although this is used in some clinical trials, like this one, to ensure compliance.]

Eczema

*Some research shows that taking vitamin D reduces **eczema (atopic dermatitis)** severity in people with moderate to severe disease and low or borderline low levels of vitamin D when used along with standard treatment.*

Achieving or maintaining a vitamin D blood level of at least 20 ng/mL was associated with a significant reduction in the severity of eczema (atopic dermatitis) in comparison to levels below 20 ng/mL in a study of 58 children and adults in Mexico with moderate to severe eczema who were also given standard treatment (topical steroid, soap substitute, and emollient). Levels of 30 ng/mL or higher provided no further benefit (Sanchez-Armendariz, Int J Dermatol 2018). A study in Egypt among 86 children and adolescents with severe eczema found that taking 1,600 IU of vitamin D3 daily for three months in addition to applying 1% hydrocortisone cream twice daily moderately reduced eczema severity compared to using hydrocortisone cream alone. The percentage of people who achieved at least 75% improvement in eczema severity was significantly higher in the vitamin D group than the placebo group (39% vs 7%). In those who took vitamin D, average blood levels of vitamin D increased from 22.8 ng/mL to 36.11 ng/mL, while levels in the placebo group did not significantly change from the baseline value of about 25 ng/mL (Mansour, Pharmacol Res Perspect 2020).

Psoriasis

Vitamin D supplementation at high dosages has not been shown to provide a significant, lasting reduction in the severity of plaque psoriasis in people with mild symptoms.

A study in Norway among 122 men and women (average age 54) with mild psoriasis and generally low blood levels of vitamin D found that supplementation with high-dose vitamin D3 did not decrease the severity of psoriasis symptoms or improve quality of life compared to placebo, despite increasing average 25(OH)D blood levels from 15 to about 30 ng/mL while levels fell about 3 ng/mL in the placebo group. Vitamin D was given at an initial dose of 100,000 IU followed by 20,000 IU once weekly for 4 months during winter (when psoriasis severity tends to worsen and vitamin D levels decrease) (Jenssen, JAMA Dermatol 2023).

A study among 45 men and women with mild psoriasis in Thailand who had not responded satisfactorily to other treatments reported a statistically significant improvement in symptoms with vitamin D relative to placebo at three months, but by six months the difference from placebo fell slightly short of statistical significance. Patients were given 60,000 IU of vitamin D2 (as three 20,000 IU capsules) every 2 weeks (averaging 4,286 IU/day) for 6 months. At the start of the study, just over one-fourth of patients had vitamin D levels

below 20 ng/mL, with an average level of 24 ng/mL and, by the end of the study, none of the vitamin D-treated patients were below 20 ng/mL, compared to 44% in the placebo group (an increase, due to seasonality), although vitamin D only raised levels, on average, by about 3 ng/mL — a surprisingly small increase considering the large dose. The researchers noted that the prevalence of vitamin D deficiency appears to be several times higher among those with psoriasis than in the general Thai population (Disphanurat, Derm Res Prac 2019).

Acne

A case control study among 160 adults with or without acne found that 48.8% of those with acne were vitamin D deficient compared to only 22.5% of those without acne, and this difference was statistically significant. A subsequent controlled study among 39 people with acne and vitamin D deficiency showed that taking 1,000 IU of vitamin D (as cholecalciferol) daily for two months significantly reduced the number of inflammatory lesions by 34.6% compared to only 5.8% in the placebo group. However, vitamin D supplementation did *not* significantly improve the total lesion count or count of non-inflammatory lesions compared to placebo (Lim, PLoS One 2016). There does not appear to be any evidence that vitamin D supplementation reduces acne among people who are *not* deficient in vitamin D.

Fibromyalgia

Fibromyalgia is a common syndrome in which a person has long-term, body-wide pain and tenderness in the joints, muscles, tendons, and other soft tissues. Some, but not all, studies suggest improvements in symptoms of fibromyalgia with vitamin D supplementation, and it would seem worthwhile to raise vitamin D levels if not already at least 20 to 24 ng/mL.

One randomized controlled study found that increasing vitamin D blood levels from a mean of 19 ng/mL to about 50 ng/mL was associated with a modest decrease in fibromyalgia pain (a 20-point decrease on a 100-point scale). The study involved 30 adults (mostly women) in Austria with fibromyalgia. Most of the participants started the study with vitamin D levels below 24 ng/mL and were given 2,400 IU of vitamin D_3 daily, while those starting with levels between 24 ng/mL and 32 ng/mL were given 1,200 IU daily. Treatment continued for 20 weeks or until vitamin D levels reached 48 ng/mL (levels in several patients went as high as 55 to 93 ng/mL). Twenty-four weeks after supplementation ended, pain returned to the original level in the group (Wepner, Pain 2013).

A study in Mexico among 80 women (average age 51) with mild to moderate fibromyalgia found that weekly supplementation with 50,000 IU of vitamin D3 for 12 weeks did not improve function or measures of fatigue, pain, anxiety or depression compared to placebo. However, 95% of those who received vitamin D were not deficient in vitamin D to start (levels were 20 ng/mL or higher, and were raised to an average of 51.8 ng/mL) and those in the placebo group who had levels below 20 ng/mL were also given vitamin D (for ethical reasons), bringing their average level up to 20 ng/mL. Symptoms scores dropped almost equally in both groups. It does not seem possible to draw a valid conclusion from this study regarding the benefit of vitamin D in treating women with fibromyalgia (Lozano-Plato, Clin Rheumatol 2021).

Insomnia

Although insomnia can occur in people with vitamin D deficiency, the evidence that vitamin D supplementation improves sleep in people with low blood levels of vitamin D is mixed. In addition, supplementation with high doses of vitamin D may decrease the quality of sleep.

Vitamin D supplementation was shown to decrease the amount of time it took to fall asleep by an average of about 10 minutes, and increase the duration of sleep by about a half-hour, in U.S. veterans with chronic pain whose 25(OH)D blood levels increased from an average of 18 ng/mL to 26 ng/mL with supplementation. However, this study did not include a placebo group, and it's not known if the improvement in sleep was a direct result of supplementation, or due to a decrease in pain that also occurred, limiting the significance of the findings (Romano, Curr Pharm Des 2020).

A placebo-controlled study in Norway among 189 men and women (average age 51) with low 25(OH)D blood levels (average 14 ng/mL) found that increasing blood levels to an average of 34 ng/mL with vitamin D3 supplementation did *not* increase sleep duration, or reduce symptoms of daytime sleepiness or insomnia, compared to placebo, even among those who reported having insomnia before

supplementation. Vitamin D3 was given for four months starting with a single, high oral dose of 100,000 IU followed by a once weekly dose of 20,000 IU — equivalent to 2,857 IU per day (Larsen, Sleep Med 2021).

Some research suggests that high-dose vitamin D supplementation may interfere with melatonin production, and some but not all studies suggest that having blood levels over 32 ng/mL may worsen sleep quality (see Concerns and Cautions).

Restless legs syndrome

Vitamin D supplementation does not appear to reduce the severity of RLS symptom, even among people with low levels of vitamin D.

A study among 141 women (average age 41) with restless legs syndrome, premenstrual syndrome (which has been linked with increased risk of RLS), and low levels of vitamin D (25(OH)D about 14.6 ng/mL) showed that drinking 200 mL (6.7 fl oz) of low-fat milk fortified with 1,500 IU of vitamin D3, or consuming 150 grams (5.3 oz) of low-fat yogurt fortified with the same amount of vitamin D, daily for 2.5 months did *not* significantly decrease the severity of RLS symptoms compared to consuming the same amount of *unfortified* yogurt or milk despite significantly increasing blood levels of vitamin D by 5.8 to 6.8 ng/mL (Sharifan, BMC Womens Health 2024).

An earlier, three-month, placebo-controlled trial among 22 men and women with restless legs syndrome also found that increasing average vitamin D blood levels from 19 ng/mL to 36 ng/mL with high-dose vitamin D supplementation (50,000 IU once a week) did *not* decrease the severity of the symptoms of RLS (Wali, Sleep Breath 2018).

Headache

Low blood levels (under 20 ng/mL) of vitamin D have been associated with a higher risk of frequent headaches and a moderate increase in migraine episodes, although it has not yet been determined whether supplementing with vitamin D provides these benefits. It may just be that people with migraine get less sun exposure due to migraine episodes and related photophobia, resulting in lower levels of vitamin D.

A study among 2,601 middle-aged men in Finland found those who had the lowest blood levels of vitamin D (under 12 ng/mL or below) were *twice as likely* to report **frequent headaches** than men with higher blood levels. About 15% of men with the lowest levels (less than 12 ng/mL) had headaches at least weekly, while the percentage was only 8% among men with levels of 12 to 16 ng/mL, 16 to 22 ng/mL, or above 22 ng/mL (Virtanen, Scientific Reports 2016). The researchers noted that vitamin D deficiency has also been associated with chronic tension-type headache, perhaps by causing musculoskeletal pain. A study in Korea among 157 men and women (average age 37) with **migraine** found that headaches occurred 20% more frequently in those who were deficient in vitamin D (< 20 ng/mL) than those who were not deficient, regardless of gender, type of migraine (chronic, episodic, with or without aura), and factors such as depression, anxiety and sleep quality. However, vitamin D deficiency was not associated with the severity of migraine episodes (Song, J Clin Neurol 2018).

A study in Spain found that women (average age 48) with migraine were more likely to have low (<20 ng/mL) or deficient vitamin D levels compared to a control group of men and women *without* migraine low. Lack of exercise and sun exposure was also strongly correlated with low/deficient levels of vitamin D, leading the researchers to speculate that, rather than low vitamin D causing migraine, migraine may lead to low vitamin D levels by reducing outdoor physical activity and sun exposure which would normally boost vitamin D levels (Haro, Headache 2025).

Lupus

A preliminary study suggests that raising low vitamin D levels with supplementation provides beneficial immunological effects in patients with **systemic lupus erythematosus (SLE)**. Giving 100,000 IU of vitamin D3 (weekly for a month and then monthly) along with regular therapy to SLE patients with generally low vitamin D levels (averaging 19 ng/mL) raised vitamin D blood levels to 42 ng/mL after 6 months of therapy, during which patients experienced no flare ups and experienced an increase in regulatory T cells and decreases in memory B cells, effector T cells, and anti-DNA antibodies (Terrier, Arth Res & Ther 2012).

Hashimoto's thyroiditis

Although (as noted earlier) vitamin D supplementation has been associated with an *increased* risk of Hashimoto's thyroiditis (an autoimmune disease that causes an enlarged, and often, underactive thyroid -- i.e. hypothyroidism), vitamin D may be helpful to people with low levels of vitamin D who already have Hashimoto's. This was seen in a study in China among 179 women (average age 34) newly diagnosed with Hashimoto's thyroiditis but who still had normal thyroid function or sub-clinical hypothyroidism, and low blood levels of vitamin D (average 15 ng/mL). The women were divided into three groups and given either 20 mcg (800 IU) of vitamin D per day, 20 mcg vitamin D plus levothyroxine (25 to 50 mcg per day), or no treatment (the control group), for six months. Compared to the control group, women who received vitamin D had significant decreases in TSH (thyroid-stimulating hormone -- elevated levels of which (> 5 mIU/L) indicate an underactive thyroid), with greater decreases seen among those who took vitamin D plus levothyroxine. Among those who took vitamin D, blood levels of vitamin D increased to an average of 24 ng/mL, and average TSH decreased from about 4.2 mIU/L to 2.49 (vitamin D alone) and 1.99 mIU/L (vitamin D plus levothyroxine). Compared to the control group, both groups who took vitamin D (with or without levothyroxine) also had significant decreases in TPOAb (thyroid peroxidase antibody -- higher levels of which can indicate more active autoimmune disease) (Jiang, Am J Transl Res 2023).

Grave's disease

Vitamin D was not found to be helpful when given to people with Grave's disease (which causes overactive thyroid), although study participants were generally not deficient in vitamin D. In the study, participants were given 70 mcg (2,800 IU) of vitamin D once daily for one year in addition to anti-thyroid medication, but this did *not* improve remission rates compared to those given placebo instead of vitamin D. In fact, those who took vitamin D (among whom blood levels of vitamin D increased to 42 ng/mL) tended to be *more* likely to fail to enter and sustain remission, although this increase in risk did not reach statistical significance (Grove-Laugesen, Thyroid 2023).

Crohn's disease

Some, but not all, research suggests that people with Crohn's disease tend to have lower blood levels of vitamin D, and that lower levels of vitamin D may be associated with disease severity (Weisshof, Curr Opin Clin Nutr Metab Care 2015). To be safe, the American Gastroenterological Association (AGA) advises that all individuals with inflammatory bowel disease (which includes Crohn's disease as well as ulcerative colitis) be monitored for vitamin D deficiency (i.e., < 20 ng/mL) (Hashash, Gastroenterology 2024).

A small study among people with mild to moderate Crohn's disease and insufficient blood levels of vitamin D found that increasing average blood levels of vitamin D from 16 ng/mL to 40 ng/mL over 24 weeks decreased average Crohn's disease activity index (CDAI) scores by 112 points (from 230 to 118 points on a scale of 0 to 600 points) but did not increase bone density compared to baseline. Participants started at a dose of 1,000 IU of vitamin D3 per day for the first week, and this dose was increased to 5,000 IU per day for most participants in order to reach a blood level of 40 ng/mL. Most participants did not have adequate calcium intake at the beginning of the trial, but average total calcium intake from diet and supplements increased from 879 mg to 1,153 mg over the course of the study (Yang, Clin Transl Gastroenterol 2013).

Irritable bowel syndrome (IBS)

A study in the UK among 135 men and women (average age 29) with mild to moderate IBS, most of whom also had low or deficient blood levels of vitamin D, found that 3,000 IU (75 mcg) of vitamin D3 taken as a sublingual spray (by BetterYou Ltd, which funded the study) daily for three months did *not* reduce symptom severity or improve quality of life compared to placebo, despite increasing average blood levels of vitamin D from 19 ng/mL to 37 ng/mL (Williams, Eur J Nutr 2021).

Menstrual pain and Premenstrual Syndrome (PMS)

A small study of women with primary dysmenorrhea (**painful menstrual cramping**) and a mean vitamin D blood level of 27 ng/mL found that giving a single high dose (300,000 IU) of vitamin D3 reduced pain by 41% during the next two menstrual periods. None of the women who received vitamin D needed anti-inflammatory medicine to manage menstrual pain during the two months, whereas 40% of

those taking placebo used it at least once (Lasco, Arch Intern Med 2012). A concern, however, is that high dose vitamin D has been shown to increase the risk of falls and fractures — at least in the elderly (as noted above) and the dose given works out to 5,000 IU vitamin D per day, more than the Tolerable Upper Intake Level of 4,000 IU per day (see Concerns and Cautions).

A study among extremely vitamin D deficient (< 10 ng/mL) adolescent and young women (ages 15 — 21) with self-reported severe or extremely severe emotional and cognitive symptoms associated with premenstrual syndrome found that high-dose supplementation (an initial dose of 200,000 IU followed by 25,000 I.U. every two weeks) with liquid vitamin D3 (*Dibase®*, Abiogen Pharma, Italy) for four months significantly reduced these symptoms: Mean scores of "irritability" decreased from 130 to 70, "crying easily" decreased from 41 to 30, sadness decreased from "51 to 31" and "disturbed relationships" decreased from 150 to 70 compared to the beginning of treatment. Those who took a placebo had a significant reduction only in "irritability" (from 128 to 119). (Tartagni, J Pediatr Adolesc Gynecol 2015). It should be noted that the dosing may have been unnecessarily high as blood levels rose to 35 to 60 ng/mL.

Polycystic Ovary Syndrome (PCOS)

A randomized, placebo-controlled study in Jordan among 58 overweight women with vitamin D deficiency and PCOS (average age 24) found that taking 50,000 IU of vitamin D_3 once weekly for 12 weeks increased 25(OH)D levels from 12.5 ng/mL at baseline to 50.2 ng/mL. Compared to placebo, women supplemented with vitamin D showed decreased levels of parathyroid hormone and testosterone, increased levels of sex hormone binding globulin, and reduced severity of hirsutism (male-patten hair growth in women). Ovarian volume, which is often increased in women with PCOS, returned to normal for 24% of women given vitamin D compared to none of the women given placebo. Also, a greater percentage of women given vitamin D experienced regular menstrual cycles compared to placebo (93% vs 10%) (Al-Bayyari, Clin Nutr 2020). The researchers did not determine if these improvements increased fertility.

Uterine fibroids

A study of women ages 35 to 49 found that those with vitamin D levels above 20 ng/mL were 32% less likely to have had uterine fibroids than those with lower levels. Similarly, women who reported getting at least one hour per day of sun exposure (weather permitting), were 40% less likely to have had fibroids than women reporting less sun exposure (Baird, Epidemiology 2013). The risk of fibroids appeared to continue to decrease as vitamin D levels approached 35 ng/mL. Possibly explaining these findings are laboratory studies showing that vitamin D in its active form inhibits the overproduction of tissue by uterine muscle cells -- the cause of fibroids. The study was conducted in Washington, D.C. in the late 1990s and only 10% of Black women and 50% of white women had vitamin D levels above 20 ng/mL. Fibroids are the leading reason for hysterectomy in the U.S.

Early menopause

Adequate intake of vitamin D from foods is associated with a lower risk of early menopause (i.e., menopause before age 45), but this does not prove a cause-and-effect relationship. Early menopause is of concern because it is associated with higher risk of cardiovascular disease, osteoporosis, and other conditions. A study of more than 80,000 women found that those who had the highest intakes of vitamin D from foods (528 IU per day -- equivalent to that found in 2.5 cups of milk per day) had a 17% lower risk of early menopause than women with the lowest intakes from food (148 IU per day) after adjusting for age, smoking and other factors. The association between intake of vitamin D from foods and reduced risk of early menopause was strongest when vitamin D was obtained from dairy foods, as opposed to non-dairy foods, although the reason for this is not clear. Intake of vitamin D from supplements was not associated with a reduced risk — and high intake of calcium from supplements (particularly 900 mg or more per day) was actually associated with an increased risk of early menopause (Purdue-Smith, Am J Clin Nutr 2017). Another large study found no association between vitamin D supplementation and early menopause, although regular use (≥ 4 times per week) of both a multivitamin *and* a separate vitamin D supplement was associated with *slightly* earlier menopause. However, the researchers suggested that women may be more motivated to take vitamin D supplements if and when experiencing menopausal symptoms, which could explain this finding. The study followed over 13,000 women in the U.S. (average age 46) for an average of six years (Jukic, Maturitas 2024).

Erectile dysfunction

Having adequate levels of vitamin D may improve the effectiveness of erectile dysfunction drugs according to two clinical trials — although neither involved a placebo control, which would make the findings more meaningful. Taking vitamin D does not seem to help men who already have sufficient levels. Vitamin D plays a role in endothelial function and in the production of nitric oxide, which are important for proper erectile function (Andrukhova, Mol Endocrinol 2014; Molinari Cell Physiol Biochem 2011).

A 3-month study in Turkey among 111 men with erectile dysfunction and low vitamin D levels (averaging 14 ng/mL) found that, compared to taking only tadalafil (Cialis)(5 mg daily), those also took 4,000 IU (100 mcg) of vitamin D3 had greater improvements in erectile function and increased sexual desire. Both groups, however, had similar improvements in orgasmic function, and sexual and overall satisfaction. Average blood levels of vitamin D increased to 35 ng/mL in the vitamin D group (Demirci, Urol Int 2021).

Similarly, a study in China among men (average age 49) with mild to moderately severe erectile dysfunction and somewhat low blood levels of vitamin D (averaging 18 ng/mL) found that a greater percentage (39% vs 16%) of those who took 10 mcg (400 IU) of vitamin D3 daily in addition to taking sildenafil (Viagra) (100 mg one hour before sex), had a clinically significant improvement in erectile function compared to those who took only sildenafil. Among those who took vitamin D, average blood levels of vitamin D increased to 45 ng/mL (an unusually large increase for a modest dose of vitamin D), while there was no significant change in vitamin D levels among those who did not take vitamin D (Yang, J Mens Health 2023).

On the other hand, taking vitamin D did *not* prevent erectile dysfunction, or improve symptoms of it, among older men (age range: 60 to 84) with *adequate* levels of vitamin D in a study among 8,920 men in Australia, about 80% of whom had blood levels of vitamin D >20 ng/mL prior to supplementation. All of the men received 60,000 IU (1,500 mcg) of vitamin D3 or placebo monthly for three years. Average blood levels of vitamin D after 3 years were 42.4 ng/mL in the vitamin D group and 30.4 ng/mL in the placebo group (Romero, Clin Nutr ESPEN 2024).

Pregnancy

As described below, an adequate vitamin D level during pregnancy is associated with better infant growth and decreased risk of pre-term labor, pre-eclampsia, and gestational diabetes. Supplementing with vitamin D to correct deficiency has also been shown to reduce health risks to the mother, improve bone mineral density in children as they grow, and possibly reduce the risk of tooth defects in children. However, high-dose vitamin D during pregnancy does not seem to reduce the risk of pre-term birth, NICU admission, or neonatal infection or improve motor or cognitive development in children, although it might reduce the risk of pregnancy loss.

Vitamin D levels in the blood of pregnant women are associated with **infant growth**. A study in the U.S. found that the birth weight and head circumference of babies rose with increasing vitamin D levels up to 15 ng/mL (Gernand, J Clin Endocrin & Metab 2012). Mothers with levels of 15 ng/mL or greater gave birth to newborns 46 grams (0.1 lb) heavier and with head circumferences 0.13 cm larger, on average, than those of mothers with vitamin D levels less than 15 ng/mL. A level of 15 ng/mL or greater in the first trimester was also associated with half the risk of an infant being small for its gestational age.

Having sufficient blood levels of vitamin D during pregnancy is also associated with a decreased risk of **gestational diabetes** (diabetes developing in pregnant women). A study among 8,468 women in China found that, among those who had 25(OH)D blood levels of 20 to 30 ng/mL (measured before 20 weeks gestation), 9.73% developed gestational diabetes compared to 12% among those with blood levels below 20 ng/mL (Yue, Nutr Metab (Lond) 2020).

A study in India evaluated the effect of giving pregnant women large doses of vitamin D. Those with already sufficient levels (above 20 ng/mL) were given a single dose of 60,000 IU D_3 at week 20 of their pregnancy (averaging about 400 IU per day over the duration of their pregnancy), and those with insufficient (10 to 20 ng/mL) or deficient (<10 ng/mL) levels were given a monthly dose of 120,000 IU twice or four times, respectively, raising the average blood level of the entire group to 32 ng/mL. In another group of women who were not given vitamin D (average vitamin D level of 18.4 ng/mL), 44% developed **pre-term labor, pre-eclampsia, and/or gestational diabetes**, in

contrast to 20.3% of the women given vitamin D. The non-treated group also had babies with a lower average birth weight (5.28 lbs) than did those given vitamin D (5.72 lbs) (Sablok, Clin Endocrinol 2015). The researchers note that lower-dose daily preparations may have been preferable to the large monthly doses but were not available.

A study in the U.S. among 392 pregnant women who, on average, already had sufficient levels of vitamin D, found that supplementing with 3,000 IU of vitamin D daily during pregnancy did *not* reduce the risk of preterm birth, low birth weight, NICU admission, respiratory distress, or infection in the infant compared to not supplementing. However, **pregnancy loss** was significantly lower and infants' **Apgar scores** (reflecting their general condition at birth) were significantly higher among women who supplemented with vitamin D compared to those who did not (Persad, Am J Obstet Gynecol 2021).

Giving expectant mothers high-dose vitamin D appears to reduce the risk of **tooth enamel defects** in their children. At age six, children of pregnant mothers in Denmark who were given vitamin D3 (2,400 IU plus another 400 IU per day) from the 24th week of pregnancy to one week postpartum had a 50% lower risk of enamel defects in baby and permanent teeth compared to children of mothers given 400 IU per day (Note: The recommended daily allowance for pregnant women is 600 IU per day). Interestingly, the women were generally not deficient in vitamin D prior to supplementation, having average blood levels of about 30 ng/mL, which increased to 43 ng/mL at one week postpartum in those who took the higher dose of vitamin D but decreased slightly to 28 ng/mL in those who took the lower dose. However, there was no association between high-dose vitamin D supplementation and the risk of cavities (Norrisgaard, JAMA Pediatr 2019).

The same study found that children of the mothers given high-dose vitamin D had greater whole body **bone mineral density** at age 6 than those of mothers given only 400 IU. However, this only held true for children of mothers who, prior to the study, had vitamin D levels *below 30 ng/mL* (an arbitrary breakpoint for analysis). There was no bone benefit from giving high-dose vitamin D to women whose levels were already sufficient. In fact, an accompanying editorial noted that giving vitamin D to women with levels above 50 ng/mL is associated with ***decreased growth*** of offspring (Holmlund-Suila, JAMA Ped 2020). The researchers noted that starting vitamin D earlier in pregnancy may have additional benefit because bone growth centers begin in the first trimester (Brustad, JAMA Ped 2020). Similarly, giving a lower but still substantial dose of vitamin D (1,000 IU daily -- in addition to up to 400 IU from other sources) to pregnant women in the UK (average vitamin D level of 18 ng/mL) from 14 weeks of pregnancy until delivery did *not*, compared to placebo, lead to greater bone mass in children -- except for children born during the winter (when vitamin D levels normally decline). However, by age 4, children of mothers who had taken vitamin D *did*, on average, have a slightly greater bone mineral density than children of mothers given placebo, and this effect was larger among children with low milk intake and low levels of physical activity. Children of mothers who had been given vitamin D also had somewhat more lean body mass (Curtis, JBMR Plus 2022). By the age of 6-7 years, children of mothers given vitamin D continued to show slightly greater *whole body* bone mineral density than children of mothers given placebo, although there was no significant between-group difference in *lumbar spine* bone mineral density, which is an indicator of bone strength in an area important for posture and movement (Moon, Am J Clin Nutr 2024).

Further analysis of results from the study in Denmark (discussed above) did *not* find benefits from prenatal high-dose vitamin D in children by age 6 with regard to motor, language, or cognitive development, nor reduced emotional or behavioral problems in comparison to those of mothers given 400 IU daily. The average blood level of vitamin D prior to high-dose supplementation was 30.6 ng/mL, with only 14% of the women having levels less than 20 ng/mL (Sass, JAMA Netw Open 2020).

Respiratory infection, colds, and influenza

Some, but not all, research suggests that vitamin D may be effective in reducing respiratory infections in people who do not already have adequate levels (20 ng/mL) of vitamin D and when vitamin D is given daily, not in extremely large, periodic doses.

An analysis of 25 studies of vitamin D for cold and flu (including some of the studies described below) concluded that vitamin D supplementation protects against **acute respiratory tract infection**, but mainly in people *very deficient* (blood levels of vitamin D below 10 ng/mL) and taking moderate doses daily or weekly doses rather than less frequent, large doses. Vitamin D appeared to reduce the

risk of infection by 42% in people with levels below 10 ng/mL, and by 70% if dosing was daily or weekly. For those with levels above 10 ng/mL, the risk reduction was only statistically significant when given daily or weekly, resulting in a 25% reduction in risk of infection (Martineau, BMJ 2017).

Not surprisingly, a large study of older people (average age 68) in the U.S., most of whom had sufficient levels of vitamin D (averaging 31 ng/mL), showed that supplementing with 2,000 IU of vitamin D daily for 1 year did *not* significantly reduce the risk of upper respiratory infections compared to placebo. The somewhat large dose also did not reduce risk in the small percentage of people who were vitamin D deficient (under 12 ng/mL) at baseline (Camargo Jr, Clin Infect Dis 2023). Similarly, a study among 61 young adults (average age 19) with adequate blood levels of vitamin D (22 to 23 ng/mL) showed that taking 800 IU (20 mcg) of vitamin D daily for 14 weeks from January through May did *not* reduce the number of acute respiratory infections or the number of days off due to infection compared to placebo, despite preventing declines in blood levels of vitamin D (final blood levels: 23.92 vs. 20.71 ng/mL for vitamin D vs. placebo) (Laaksi, Open Forum Infect Dis 2024). On the other hand, a study in Denmark among 189 children (age range: 6 to 8 years) with adequate blood levels of vitamin D at baseline (averaging 32 ng/mL) showed that taking chewable tablets containing 800 IU (20 mcg) of vitamin D3 (Minisun by Oy Verman) once daily with a meal for 24 weeks mainly during the winter not only prevented the decline in vitamin D blood levels that occurred in the placebo group (averaging +3.8 vs -13.1 ng/mL, which left many in the placebo group below 20 ng/mL), but those receiving vitamin D had 17% fewer sick days due to acute respiratory tract infections and 43% fewer days of respiratory infections with fever compared to the placebo group (Clerico, Eur J Nutr 2025).

Two studies showed that supplementing with vitamin D in large monthly doses (generally 60,000 IU to 100,000 IU monthly) did *not* reduce the number of upper respiratory infections compared to placebo, although people in these studies were healthy adults with generally sufficient vitamin D levels (Murdoch, JAMA 2012; Pham, Lancet Diabetes Endocrinol 2021).

A study in London among 194 older residents of group homes and 46 of their caregivers (average age was 67 years), 64% of whom had low blood levels of vitamin D (<20 ng/mL), found that the residents who received 400 IU of vitamin D3 daily along with 96,000 IU every two months (which averaged to 2,000 IU daily) and the caregivers who received 120,000 IU of vitamin D every two months (which also averaged to 2,000 IU daily) for one year were 48% *more likely* to develop an upper respiratory infection than those who did not receive the large doses (i.e., residents who received only 400 IU of vitamin D daily and caregivers who did not receive vitamin D supplements). These infections also lasted longer for those receiving the large dose (7 days vs. 5 days, respectively). Interestingly, those receiving large doses had an average level of 34 ng/mL at the end of the study (2 months after the last large dose), while those who did not receive large doses (most of whom received just 400 IU daily) and had fewer respiratory infections ended the study with levels averaging 24 ng/mL (Martineau, Thorax 2015).

COVID-19

Most, but not all, studies have linked adequate levels of vitamin D in people who develop COVID-19 with less severe disease, decreased need for intensive care and ventilation, and a lower risk of death. Similarly, some, but not all preliminary research suggests that supplementing with moderate to high vitamin D when vitamin D levels are low (about 20 ng/mL or lower) may improve prognosis in people hospitalized with COVID-19, but extremely high single doses have not been shown to help. There appears to be an increased risk of COVID-19 in people with very high levels of vitamin D.

Reduced risk of COVID-19

Several studies have linked low levels of vitamin D to a higher risk of COVID-19 infection (Faniyi, medRxiv 2020 - preprint; Merzon, FEBS J 2020; Meltzer, JAMA Netw Open 2020; Meltzer, JAMA Netw Open 2021). Although vitamin D supplementation may help prevent COVID-19 among *unvaccinated* people with low blood levels of vitamin D, it may not help people who are vaccinated or those with adequate levels of vitamin D (Jolliffe, BMJ 2022; Brunvoll, BMJ 2022).

A study in Mexico among 302 unvaccinated healthcare workers with no history of COVID-19, 64% of whom were vitamin D deficient, showed that supplementing with 4,000 IU of vitamin D3 daily for 30 days reduced the risk of COVID-19 infection by 77% compared to placebo (cornstarch), with a slight, but not significantly, greater benefit (80% reduced risk) among the subgroup of individuals who were

vitamin D deficient. The average starting level of 25(OH)D was 18.3 ng/mL, and those receiving vitamin D showed an average increase of 8.8 ng/mL (Villasis-Keever, Arch Med Res 2022). It is unclear from this study if vitamin D supplementation would have similar benefit among vaccinated individuals or those starting with higher levels of vitamin D.

Reduced severity of disease, need for intervention, and death

Low blood levels of vitamin D (generally below 20 ng/mL) have been associated with more severe respiratory symptoms and/or higher risk of death from COVID-19 compared to blood levels in the 20s and 30s (Carpagnano, J Endocrinol Invest 2020; Panagiotou, letter in Clin Endocrinol (Oxf) 2020; Radujkovic, Nutrients 2020; Lau, medRxiv 2020 — preprint; Angelidi, Mayo Clin Proc 2021; Dror, PLOS ONE, 2022). However, taking high-dose vitamin D (averaging 1,800 IU/day) did not decrease these risks, according to one study, discussed below. Furthermore, having *high* blood levels of vitamin D has been linked with *increased* risk of death due to COVID-19.

A study in Italy that focused on COVID-19 patients taking doses of vitamin D equivalent to 800 IU or higher per day (mean intake 1,800 IU daily) during the prior 3 months (and excluding those taking lower doses) showed *no lower risk of hospitalization or in-hospital mortality* compared with those who did *not* take vitamin D supplements, despite almost three-fold higher blood levels of vitamin D (32.9 ng/mL vs 11.3 ng/mL, respectively) (Cereda, Nutrition 2020).

Having high blood levels of vitamin D has also been associated with an *increased* risk of death from COVID. A study among 472 people hospitalized with COVID in the UK found that, after adjusting for age, sex and comorbidities, the risk of death at 28 days was 137% higher for those who were vitamin D deficient (25(OH)D of < 10 ng/mL), and *365% higher* for those with a vitamin D level at or above 40 ng/mL, compared to those with blood levels between about 20 and 30 ng/mL (Subramanian, Am J Clin Nutr 2022). The increased risk at lowest and highest blood levels of vitamin D follows a similar pattern seen with risk of mortality in general and with other adverse effects for vitamin D (see How Much Do I Need and How Much Is Too Much for more about this).

Treatment of COVID-19 patients

As described below, there has been mixed evidence as to whether or not patients hospitalized with COVID-19 benefit from vitamin D or a form of vitamin D (calcifediol). It remains uncertain what dose, if any, is most effective, and any benefit seems to be limited to only those who are vitamin D deficient.

The following studies reported a benefit:
A study in Belgium among 43 people (average age 66) hospitalized with COVID-19 who were vitamin D deficient (defined as blood levels of 25(OH)D_3 <20 ng/mL) showed that taking 25,000 IU of vitamin D3 (D-CURE, Laboratoires SMB SA) daily for 4 days, followed by 25,000 IU weekly (about 3,570 IU daily) until hospital discharge (for a maximum duration of 6 weeks), reduced the average duration of hospitalization by 50% (4 days vs. 8 days) and the duration of supplemental oxygen by 42% (4 days vs. 7 days) compared to placebo. However, there was no difference in the duration of fever, the number of people admitted to the ICU or duration of ICU stay, or the risk of all-cause or COVID-19-related mortality. Vitamin D supplementation increased blood levels of 25(OH)D3 from 17.87 to 29.9 ng/mL, while those given placebo showed no change in blood levels of vitamin D. Most of the people (>86%) in this study were *not* vaccinated (De Niet, Nutrients 2022).

A study in India among people diagnosed with mild or asymptomatic COVID-19 found that 62% achieved SARS-CoV-2 negativity after 14 days of high-dose vitamin D treatment compared to just 20.8% in a control group. Vitamin D was given as 60,000 IU daily for 7 days, followed 60,000 IU either daily or once weekly for another week (depending on blood levels of vitamin D after the first week). Blood levels of vitamin D were increased from 8.6 ng/mL to 51.7 ng/mL after 14 days for those in the vitamin D group (Rastogi, Postgrad Med J 2020).

A study in Singapore among 43 men and women ages 50 or older hospitalized with COVID-19 found that those who were started on a daily oral dose of vitamin D3 (1,000 IU), magnesium (150 mg) and vitamin B-12 (500 mcg) within the first day of hospitalization and continued for up to 14 days were about 71% less likely to require oxygen therapy and further intensive care compared to those not receiving the supplements. However, blood levels of vitamin D, magnesium and B-12 were not measured, so it's not known if any of the patients were deficient before supplementation (Tan, Nutrition 2020).

A study found that elderly residents of a nursing home in France who had been given a high-dose (80,000 IU) vitamin D in the previous month or in the week following COVID-19 diagnosis showed 86% greater survival at one month after COVID-19 diagnosis compared to those who did not receive supplementation (Annweiler, J Steroid Biochem Mol Biol 2020).

A study in Córdoba, Spain (where average blood level of vitamin D is about 16 ng/mL) among 76 people hospitalized with COVID-19 infection (all of whom were given hydroxychloroquine and azithromycin) found that those also given 532 mcg of calcifediol (a 25-hydroxylated form of vitamin D) on the day of admission followed by 266 mcg of calcifediol on day 3 and day 7 of hospitalization had a lower risk of being admitted to the ICU for complications compared to those not given calcifediol (2% with calcifediol vs 50% without), as well as a lower risk of death compared to those not given calcifediol (0 deaths with calcifediol vs 2 deaths without) (Castillo, J Steroid Biochem Mol Biol 2020). Bear in mind that the dose of calcifediol used in this study was very high. Prescribed doses of calcifediol (for its approved indications) are typically much lower (about 30 to 60 mcg per day) than those used in this study. Excessive intake of vitamin D in any form, including as calcifediol, can increase the risk of hypercalcemia (see Concerns and Cautions). Finally, calcifediol is a prescription medicine in the U.S. and is not available in supplements.

The following studies showed no benefit:
A study in India among 156 adults with blood levels of vitamin D at the lower end of adequate (average 25(OH)D 20.8 ng/mL) who were hospitalized with COVID-19, most of whom had received at least one COVID-19 vaccine prior to being hospitalized, showed that receiving a single dose of 180,000 IU of vitamin D followed by 2,000 IU of vitamin D daily, with or without 40 mg/day of zinc, for 8 weeks did *not* shorten the time until resolution of symptoms such as fever, cough, or shortness of breath compared to not receiving vitamin D, nor did it reduce the need for assisted ventilation or shorten the time to hospital discharge (Partap, Curr Dev Nutr 2023).

A 4-week study in Utah in which extended-release calcifediol or placebo was given to 134 people with COVID-19 found that calcifediol did *not* shorten the time for symptoms to resolve compared to placebo. It is notable that patients already had sufficient levels of 25(OH)D (averaging 37 ng/mL), which was increased to an extraordinary level of 82 ng/mL. Further analysis of the data suggested possible shortening of some respiratory symptoms, but the results were not statistically significant. The daily dose given to patients was 300 mcg for the first 3 days and 60 mcg for the duration. The study was funded by the drug's developer, OPKO Health, and its employees were among the authors (Bishop, medRxiv 2022 — preprint).

Two studies among people hospitalized with moderate to severe COVID-19 found that giving a single, oral dose of vitamin D3 (100,000 IU or 200,000 IU) at the time of admission did *not* reduce the length of hospital stay, risk of admission to ICU, or death compared to not giving vitamin D compared to control (no supplementation or placebo), despite the fact that most patients in both studies had low (but not deficient) blood levels of vitamin D at the time of admission (Cannata-Andia, BMC Med 2022; Murai, medRxiv 2020 — preprint; Murai, JAMA 2021). It should be stressed that these patients were given vitamin D due to high frequency of vitamin D deficiency (not as COVID-19 treatment) and that more frequent (daily or weekly) use of lower dose vitamin D to treat deficiency is preferable whenever possible (see How Much Is Too Much).

Ear infection (Otitis media)

Among children ages 1 to 5 years with a history of recurrent ear infections, those with higher blood levels of vitamin D had a decreased risk of developing *un*complicated ear infections (acute otitis media) during a 6-month study including wintertime. However, the study found that higher vitamin D levels did not reduce the risk of *complicated* ear infections (e.g., ear drum rupture). In fact, rates of complicated infections were actually higher at vitamin D levels above 30 and 40 ng/mL than at lower levels, leading the researchers to speculate that these higher vitamin D levels potentially foster certain bacterial infection in the ear. The study also found that giving 1,000 IU daily for 4 months raised vitamin levels from about 26 ng/mL to 37 ng/mL, while levels fell to about 19 ng/mL in children receiving placebo (due to reduced sun exposure in winter). Although the children receiving vitamin D experienced significantly fewer episodes of uncomplicated ear infections, there was no significant reduction in complicated infections (Marchisio, Pediatr Infect Dis J 2013). It would seem best for children to follow the recommendations for vitamin D outlined in the Summary above.

Hearing loss

An analysis of health data of 1,123 older people (average age 76) found that hearing loss of speech-frequency and low-frequency (low-pitch) sounds was about twice as great for those with low levels of vitamin D (total 25(OH)D < 20 ng/mL) compared to those with levels of 30 ng/mL or more, although there was no increased risk for those with levels between 20 ng/mL and 29 ng/mL. There was no association between vitamin D levels and the odds of high-frequency hearing loss, which is the most common form of hearing loss (Szeto, Am J Clin Nutr 2020). Note that this analysis only showed association and does not establish cause-and-effect relationships.

Depression & Mood

Lower levels of vitamin D (below 20 ng/mL) and lower dietary intake of vitamin D (less than 100 IU) have been associated with a higher risk and severity of depression in some studies (Milaneschi, J Clin Endocrinol Metab 2010; Llewellyn, Arch Intern Med 2010; Bertone-Johnson, Am J Clin Nutr 2011). However, taking vitamin D has not been shown to help most people who have depression, even those with low levels of vitamin D, other than in one study involving people who also had diabetes. Taking very large amounts of vitamin D may actually worsen certain measures of depression.

A 6-month pilot study in the U.S. suggested that high-dose vitamin D (50,000 IU of vitamin D2 per week) significantly improved mood in women with type 2 diabetes who had serious depressive symptoms. Mean serum blood levels of vitamin D increased from 18.8 ng/mL to 37.5 ng/mL during the intervention. The study also showed a modest improvement in systolic blood pressure and a slight decrease in weight. Although promising, *the study had no control group* (Penckofer, Abstract from ADA Scientific Sessions 2013).

Nevertheless, a subsequent study among 64 men and women in Iran with type 2 diabetes and mild to moderate depression who had generally low blood levels of vitamin D also found that 4,000 IU of vitamin D3 taken daily for three months decreased symptoms of depression by an average of 27.6%, which was significantly greater than among those given a placebo who experienced an average 10.8% decrease in symptoms. Average blood levels of vitamin D increased in the treated group from 15 ng/mL to 32 ng/mL. Those who took vitamin D also showed modest improvements relative to the placebo group in HbA1c (- 0.5% vs - 0.07%) and blood insulin levels (- 0.7 vs 0.1 mU/L), although there were no significant changes in fasting blood sugar or cholesterol levels (Omidian, Diabetes Metab Syndr 2019).

Among people with low levels of vitamin D but *without* diabetes, vitamin D supplementation has generally not been shown to reduce depression. A placebo-controlled study in Denmark among 62 men and women diagnosed with mild, moderate or severe depression found that daily supplementation with 70 mcg of D3 (2,800 IU) for six months did not improve depression scores - even among those who were deficient in vitamin D (< 10 ng/mL) before supplementation. Average blood levels of vitamin D rose from 17 ng/mL to 39 ng/mL during the study (Hansen, BMC Res Notes 2019).

A year-long, placebo-controlled study among 151 older men and women (average age 67) in the Netherlands with moderate depression and somewhat low average blood levels of vitamin D (18 ng/mL) also failed to find a benefit. Among those who took vitamin D (1,200 IU per day) and maintained a calcium intake from foods and/or supplements of approximately 1,000 mg per day, vitamin D blood levels increased to 34 ng/mL, but there were no significant improvements in symptoms of depression or anxiety, and no improvements in physical and cognitive function compared to those who took a placebo and whose average blood levels of vitamin D remained relatively low (average 17 ng/mL) (de Koning, Am J Clin Nutr 2019).

Vitamin D supplementation does not appear to reduce the occurrence of depression among people with adequate levels of vitamin D (20 ng/mL or more) (Choukri, J Nutri Sci 2018; Okereke, JAMA 2020). In fact, a study in Australia in which 20,487 older adults (average age 69) supplemented with 60,000 IU of vitamin D3 or placebo monthly for an average of 5 years found that vitamin D supplementation did *not* reduce the risk of experiencing clinically relevant depression, regardless of vitamin D status at baseline, and, among people with adequate levels of vitamin D at baseline who were not taking antidepressants, supplementing with vitamin D *increased* the risk of antidepressant use by 10% compared to placebo (Rahman, Int J Geriatr Psychiatry 2022).

Alzheimer's disease, dementia, memory and cognitive decline

Studies indicate that maintaining a vitamin D level of at least 20 ng/mL may be helpful in reducing the risk of developing Alzheimer's disease. Supplementing with ***moderate doses*** *of vitamin D also seems to modestly improve cognition in older individuals with mild cognitive impairment who are vitamin D deficient, but* ***high doses have not been shown to help*** *nor boost cognitive performance in adults who are not cognitively impaired. Preliminary evidence suggests that regular use of a potent prescription form of vitamin D (calcitriol) may increase the risk of developing Alzheimer's disease.*

Reducing dementia risk?

A study that followed 1,658 older adults in the U.S. for a mean period of 5.6 years found that the risk of developing dementia was increased for people with starting blood levels of vitamin D below 20 ng/mL. All participants were relatively healthy at the start of the study. People who began the study with a level of 10 ng/mL up to 20 ng/mL were 53% and 69% more likely to develop **dementia and Alzheimer's disease**, respectively, than those with starting levels of 20 ng/mL and above; and people with levels below 10 ng/mL were 125% and 122% more likely to develop dementia and Alzheimer's disease, respectively, than those starting with levels of 20 ng/mL or above. While the study suggests that adequate levels of vitamin D may be beneficial, it did not test whether raising a person's vitamin D level reduces the risk of dementia. However, as the researchers note, it clarifies that having a level above approximately 20 ng/mL is unlikely to further reduce the risk of developing dementia (Littlejohns, Neurology 2014).

Similarly, a study among 916 healthy older men and women in France (average age 73) who were followed for an average of 11.4 years found that those starting with vitamin D levels below 20 ng/mL had *nearly triple the risk of developing Alzheimer's disease* during the study than those starting with levels at or above 20 ng/mL. In addition, those who began the study with vitamin D blood levels below 10 ng/mL also had significantly faster rates of cognitive decline, and were more likely to have high cholesterol and triglycerides than those with levels at or above 10 ng/mL (Feart, Alzheimer's & Dementia 2017). Another study that followed older, ethnically diverse adults in California for a mean period of 4.8 years found that rates of decline in two areas of cognitive functioning — episodic memory (word list learning) and executive functioning — were greater among those starting with vitamin D levels below 20 ng/mL than those starting with levels of 20 ng/mL and above. Declines in these two areas are strongly associated with Alzheimer's dementia. Vitamin D status was not associated with rates of decline in two other cognitive areas: semantic memory (object naming and picture association) and visuospatial ability. The average starting level of vitamin D among the participants was 19.2 ng/mL (Miller, JAMA Neurol 2015)

A study in France among women 75 years of age and older found those with higher intakes of vitamin D from their diets were least likely to develop Alzheimer's disease over a seven-year study period. Women consuming more than 3,108 IU of vitamin D per week (444 IU per day) were 77% less likely to develop Alzheimer's disease than those with lower vitamin D intake. There was, however, no association between vitamin D intake and the risk of developing other types of dementia. The study excluded women who had taken vitamin D supplements (Annweiler, J Gerontol A Biol Sci Med 2012).

Preliminary evidence from Taiwan suggested that regular daily intake of calcitriol (a prescription drug that is an active metabolite of vitamin D) may *worsen* the progression of Alzheimer's disease. A review of national records found that, over an eleven-year period, older adults taking 0.25 mcg of calcitriol at least 146 days per year were 1.8 times more likely than similar individuals to develop Alzheimer's disease, and adults with Alzheimer's taking this level of calcitriol were 2.17 times more likely to die than those who did not take calcitriol. Less frequent use was associated with lower or no increased likelihood of Alzheimer's or death. It is important to note that calcitriol is more potent than supplemental vitamin D and more likely to cause hypercalcemia and adverse effects. In addition, these findings are only associations and do not prove cause-and-effect. Nevertheless, based on these findings and experimental findings in mice, the researchers cautioned against long-term vitamin D supplementation by older adults or individuals with Alzheimer's disease (Lai, Aging Cell, 2022).

Improving cognition?

A 12-month, placebo-controlled clinical trial in China among 181 older individuals with **mild cognitive impairment (MCI)** found that vitamin D supplementation (400 IU daily, taken with or after a meal) resulted in modest but statistically significantly improvements in cognitive functioning shown in verbal and performance tasks. The vitamin D and placebo groups each started with average vitamin D

levels of about 19 ng/mL, which increased to 23.4 ng/mL in the vitamin D group. Total cholesterol levels also decreased modestly in the vitamin D group relative to the placebo group, driven by decreases in triglycerides and, unexpectedly, HDL ("good") cholesterol (Note: Vitamin D has had mixed effects on cholesterol levels, and high doses may even increase total cholesterol) (Hu, J Neurol Neurosurg Psychiatry 2018).

Another study in China among 183 older people (average age 67) with MCI found that taking 800 IU of vitamin D daily for 12 months modestly improved overall cognitive function based on the full-scale intelligence quotient (FSIQ) score. People given vitamin D showed a 1.81% increase in FSIQ score, while those given placebo showed a 3.28% *decrease* in FSIQ score. People in the vitamin D group also showed improvements in some verbal measures (such as vocabulary and short-term verbal memory) and non-verbal measures (such as visuoconstructional ability and ability to interpret social situations) based on the Wechsler Adult Intelligence Scale-Revised score compared to those given placebo. Blood levels of vitamin D_3 increased from 19.07 ng/mL to 23.38 ng/mL for people in the vitamin D group. Interestingly, vitamin D also *increased* telomere length (measured in the DNA of white blood cells), which may be of potential benefit, as decreased telomere length may be a factor in predicting progression of cognitive decline (Yang, J Alzheimer's Dis 2020).

However, a 6-month trial in London and Canada among 170 older men and women with mild cognitive impairment, most of whom already had sufficient blood levels of vitamin D, found that supplementation with high-dose vitamin D (10,000 IU (250 mcg) taken three times per week) did *not* improve cognitive outcomes. This was the case regardless of whether vitamin D was taken alone or in combination with exercise (one hour of aerobic and resistance exercise three times weekly), cognitive training (visual-motor tasks performed on an iPad for 30 minutes three times weekly), or exercise plus cognitive training. The combination of exercise and cognitive training improved cognition, although none of the interventions alone (exercise, cognitive training, or vitamin D alone) improved cognition (Montero-Odasso, JAMA Open 2023; Montero-Odasso, Alzheimers Dement 2022).

Also, a 2-year study in the U.K. among nearly 340 older adults (average age 61) with **age-related cognitive decline** and low blood levels of vitamin D (16.8 ng/mL) showed that taking 4,000 IU (100 mcg) of vitamin D once daily did *not* improve measures of cognitive function, including executive function, spatial working memory, or numerical working memory, nor did it improve activities of daily living or well-being, compared to placebo (Corbett, J Am Med Dir Assoc 2025).

High-dose vitamin D supplementation for four months did *not* improve **cognitive functioning in healthy middle-aged and older adults** in Norway with low blood levels of vitamin D (average level of 13.6 ng/mL). Participants in the placebo-controlled study were given a starting dose of 100,000 IU of vitamin D followed by 20,000 IU taken weekly, boosting average levels to 35.6 ng/mL (Jorde, J Neurologic Sci 2018). Similarly, a large study in Australia among 4,019 healthy older adults (age range 60 to 84), most of whom had sufficient blood levels of vitamin D (20 ng/mL or more), showed that monthly oral doses of vitamin D3 (60,000 IU) for up to 5 years did *not* improve cognition or slow the development of cognitive impairment compared to placebo, regardless of age, blood levels of vitamin D, or memory at baseline (Pham, J Am Geriatr Soc 2023).

Parkinson's disease

A study from Finland suggested that higher vitamin D status provides protection against Parkinson's disease. People with the highest vitamin D levels (above 20 ng/mL) had a 65% lower risk of developing Parkinson disease than those with the lowest vitamin D levels (below 10 ng/mL)(Knekt, Arch Neurol 2010).

Multiple sclerosis

Although research suggests that vitamin D deficiency is a **risk factor for developing multiple sclerosis (MS)**, it is not clear that supplementing with vitamin D reduces the risk. An FDA review concluded that, in healthy people, there is "no credible evidence of a relationship between intake of vitamin D and a reduced risk of MS" (FDA Constituent Update 2018). There is mixed evidence as to whether vitamin D levels of pregnant mothers correlate with MS risk in their children, but one study (in Finland) found that the risk of MS as an adult was 90 percent higher in children of mothers who were significantly deficient in vitamin D (levels less than 12.02 ng/mL) compared with the children of mothers with levels between 12.02 ng/mL and 20.03 ng/mL (Munger, JAMA Neurol 2016).

Vitamin D supplementation does *not* appear to decrease the risk of MS diagnosis among people with **clinically isolated syndrome (CIS)**, a first episode of neurologic symptoms that may or may not develop into MS, even among those with low blood levels of vitamin D. A placebo-controlled study in Australia and New Zealand among 182 men and women (average age 37) with CIS who already had, on average, sufficient blood levels of vitamin D (average 28 ng/mL) found that supplementation with moderate to high-dose vitamin D (1000, 5000, or 10,000 IU taken once daily for about 11 months) did not decrease the risk of conversion from CIS to MS. There was also no decrease in risk of MS diagnosis when researchers analyzed a smaller subset of participants who began the study with very low blood levels of vitamin D (< 12 ng/mL) (Butzkueven, Brain 2023).

Low blood levels of vitamin D have also been associated with *increased disease activity* in **relapsing-remitting MS** (Mowry, Ann Neurol 2012; Fitzgerald, JAMA Neurol 2015), and laboratory research on blood samples from people with MS suggested that vitamin D may enhance the effects of interferon ß-1b treatment (Feng, Neurol Neuroimmunol Neuroinflamm 2019). However, results of several clinical trials investigating the effects of vitamin D supplementation on disease progression and relapse rates in people with relapsing MS and low levels of vitamin D who were being treated with interferon ß-1a or interferon ß-1b have generally *not* found a benefit (Camu, Neurol Neuroimmunol Neuroinflamm 2019; Hupperts, Neurology 2019). In addition, a study among 165 men and women (average age 34) with relapsing-remitting MS and low blood levels of vitamin D (15 ng/mL) and were started on daily Copaxone injections along with either high-dose vitamin D3 (5,000 IU, or 125 mcg per day) or a lower dose (600 IU, or 15 mcg per day) daily for almost two years found no difference in the percentage who experienced clinical relapse. The study did not include a placebo or control group, limiting the significance of these findings, although the annualized relapse rates for both groups were within expected ranges. The researchers speculated that people with MS, due to limitations of the disease, may be less likely to spend time outdoors getting sun exposure, and that this might explain, in part, the association between low blood levels of vitamin D and MS found in other studies — although this would not explain studies that have found increased risk of *developing* MS (Cassard, eClinicalMedicine 2023).

Autism Spectrum Disorder

Low blood levels of vitamin D have been associated with increased risk of autism spectrum disorder. Preliminary clinical research suggests that vitamin D given to children with autism spectrum disorder and vitamin D deficiency may improve symptoms. There is no evidence that vitamin D improves symptoms of autism in children who already have adequate levels of vitamin D.

A study in the Netherlands found that children whose mothers had very low vitamin D blood levels (< 10 ng/mL) during pregnancy (measured during the fifth month of gestation) were *3.8 times* as likely to have autistic traits by age six than those whose mothers had sufficient vitamin D levels (20 ng/mL). Even with levels between 10 and 19 ng/mL, there was a 75% higher risk, although this was not deemed statistically significant (Vinkhuyze, Mol Psychiatry 2016). The researchers noted that vitamin D is involved in the production of the neurotransmitter serotonin, which may play a role in certain autistic characteristics.

Similarly, a study in China found that infants with very low levels of vitamin D at birth were more likely to have autism spectrum disorder on follow up at age 3 than those with moderate levels. The average level in autistic children was just 7 ng/mL compared to 16 ng/mL in non-autistic children. It was predicted that the lowest risk of autism was among babies with a blood level of 19.2 ng/mL, as risk was seen to increase above this level (Wu, J Bone Mineral Res 2017).

In 2016, researchers in Egypt reported an association between lower blood levels of vitamin D and higher severity of autism symptoms. They also reported that treating children with autism spectrum disorder (ages 3 to 10) with high-dose vitamin D (about 5,000 IU daily, as drops) for four months resulted in a reduction in symptoms, while there was no change among children given placebo drops (Saad, J Child Psychol Psychiatry 2016). ***However, irregularities later discovered in how the data was collected and analyzed led the editors of the journal in which the report was published to retract it in 2019, stating they "... no longer have confidence in the findings reported in the original paper." (Editors, J Child Psychol Psychiatry 2019)***.

A placebo-controlled trial in Iran among 43 children with autism spectrum disorder (ages 3 to 13, average age 9), most of whom were vitamin D deficient at the beginning of the study, found that giving 300 IU/kg of vitamin D daily (up to a maximum dose of 6,000 IU/day) for 15 weeks increased the average blood level of vitamin D from just 8.19 ng/mL to 39.10 ng/mL and modestly reduced autism severity based on the childhood autism rating scale (CARS) and autism treatment evaluation checklist (ATEC), which focus on various

symptoms and skills. However, supplementing with vitamin D did not improve aberrant behaviors such as irritability, hyperactivity, social withdrawal, and inappropriate speech. Note that the dose given was extremely high, particularly for children. Lower doses would be safer and still able to treat deficiency (Javadfar, Nutrition 2020).

Executive functioning and cognitive performance

Executive functioning refers to the set of mental skills that help you get things done, like planning and strategic thinking. Maintaining a sufficient level of vitamin D appears to be associated with better executive functioning, according to a study in Norwegian adolescents. The study found that adolescents with low vitamin D blood levels (below 20 ng/mL) scored worse on tests of executive functioning and were more likely to report attention issues than those with higher levels. It also found that giving 1,520 IU (or 38 mcg) of vitamin D_3 daily for three months (which increased average vitamin D blood levels from 17.6 ng/mL to 24.8 ng/mL) improved performance on the most demanding executive functioning tasks -- although not on easier tasks (Grung, Scan J Psychol 2017). A preliminary study among Norwegian men also suggests a positive association between vitamin D blood levels of 20 ng/mL and above and better executive functioning (Hansen, Percept Motor Skills 2011).

A one-year study among 42 postmenopausal women in New Jersey who were overweight or obese found that a daily dose of 2,000 IU of vitamin D resulted in better performance in visual and working memory and learning than 600 IU or 4,000 IU. The 4,000 IU dose seemed to negatively impact reaction time, as that group had a slower reaction time than the 600 IU group. The average starting vitamin D blood level was 22.6 ng/mL, increasing to 30.2, 36, and 40.8 ng/mL, respectively, in the 600, 2,000, and 4,000 IU groups (Castle, J Gerontol Series A 2019). Note: Obese people tend to require larger doses of vitamin D to raise blood levels than people who are not overweight.

Weight control

Vitamin D does not appear to play a role in weight control. Raising blood levels of vitamin D from an average of 13 ng/mL to 24 ng/mL increased lean body mass (muscle) by about 1 lb. (as noted earlier) but did *not* decrease BMI or body fat in healthy in active men and women in Japan who supplemented with 420 IU of vitamin D for one year (Sun, Ann Nutr Metab 2019).

Similarly, a 12-month study found that taking vitamin D_3 had no overall effect on weight or fat loss in overweight or obese postmenopausal women consuming a reduced calorie diet and following a program of 45 minutes of aerobic 5 days per week (Mason, Am J Clin Nutr 2014). Regardless of whether they took 2,000 IU vitamin D_3 daily or a placebo, women lost an average 16 lbs. (Note: The 2,000 IU dose of vitamin D is fairly high for regular daily use, particularly in this study in which average vitamin D blood levels were above 20 ng/mL to start. Seven percent of the women taking vitamin D achieved levels above 50 ng/mL, which is potentially harmful. In fact, a subsequent analysis of this study found that those who received vitamin D *lost* strength in their leg muscles -- see "Muscle, balance, and falls" above.) Interestingly, among the vitamin D-treated women, those who achieved blood levels greater than 32 ng/mL lost more weight than those whose levels remained below 32 ng/mL (19 lbs vs. 12 lbs) and had greater reductions in their waistlines (3.5 inches vs. 2.2 inches) and body fat. *However, it may just be that vitamin D levels in the blood rose more in women who lost more fat*, due to the fact that vitamin D is fat soluble and stored within fat; indeed, an earlier study by the same researchers showed that weight loss raises vitamin D levels (Mason, Am J Clin Nutr 2011).

Frailty

Having a blood level of vitamin D that is either low or high has been associated with frailty. A study found that older women (69 years and older) whose vitamin D levels were not between 20 and 29.9 ng/mL had a greater risk of being frail (Ensrud, J Clin Endocrinol Metab 2010). Frail individuals were those experiencing at least three of the following criteria: weight loss, weakness, exhaustion, slowness, and low physical activity. The risk of frailty was increased by 47% among those with vitamin D levels below 15 ng/mL, 24% among those with levels below 20 ng/mL, and 32% among those with levels above 29.9 ng/mL. An average of 4.5 years after these measurements were made, those originally not frail but whose blood levels had been below 20 ng/mL were 21% more likely to have become frail or died. These findings correspond with the 2010 report from the Institute of Medicine (IOM) indicating that 20 ng/mL is a sufficient level for vitamin D and that levels above 30 ng/mL may be associated with certain risks (Food and Nutrition Board 2010).

Be aware that taking high-dose vitamin D was *not* shown to decrease frailty in a large U.S. study (the "VITAL" study) in which adults (average age 67) who were generally not deficient in vitamin D (average starting levels of around 28 ng/mL) were given 2,000 IU of vitamin D daily for 5 years. Giving 1 gram of fish oil daily also did not reduce the risk of frailty (Orkaby, JAMA Net Open 2022).

Cancer

In general, studies suggest that vitamin D supplementation does not reduce the overall incidence of cancer (at least not in people with sufficient levels of vitamin D — so it would be reasonable to maintain a vitamin D level above 20 ng/mL). However, it may decrease tumor invasiveness and mortality among some people with existing cancer. To reduce the risk of death from cancer, it would be reasonable to maintain levels into the upper 30's. For prostate cancer, the "sweet spot" may be more limited -- to between 23 ng/mL and 29 ng/mL, while for colorectal cancer it may be higher — up to 39 ng/mL. Vitamin D supplementation does not generally appear to increase survival rates among people being treated for cancer, but having a blood level of at least 24 ng/mL at the start of treatment for advanced or metastatic colorectal cancer is associated with increased survival rates. Nevertheless, giving vitamin D in very large, infrequent doses (as opposed to smaller daily doses) does not appear to be helpful.

A major study (the VITAL study) of a cross-section of older Americans (25,871 participants) given 2,000 IU of vitamin D daily for median of 5.3 years found no overall reduction in invasive cancers and death from cancer relative to placebo, although few participants were vitamin D deficient: The average starting blood level was 30.8 ng/mL and increased to over 40 ng/mL with vitamin D supplementation. *However*, when excluding the first two years of the study, the **rate of *death* from cancer** was found to be 25% lower with vitamin D than with placebo. As noted in the study, the results are consistent with other studies: In people who already have sufficient blood levels of vitamin D, supplementing with vitamin D may not reduce the overall incidence of cancer, but may decrease tumor invasiveness and the propensity to metastasize (Manson, NEJM 2018).

A secondary analysis of results from the VITAL study found that vitamin D modestly reduced the **risk of *advanced cancer*** (i.e., cancer that was metastatic or fatal) compared to placebo. Advanced cancer occurred in 2.1% of people in the placebo groups compared to 1.7% of people in the vitamin D group (17% reduction). When results were analyzed based on BMI of the people in the study, the incidence of advanced cancer was reduced by 38% for those with a normal BMI (BMI <25) but not for those who were overweight (BMI 25 to <30) or obese (BMI 30 or more) (Chandler, JAMA Netw Open 2020).

A three-year, placebo-controlled study among 2,157 generally healthy men and women age 70 and older (average age 75) in five European countries without a history of cancer, 40.7% of whom had blood levels of vitamin D below 20 ng/mL, found that daily supplementation with 50 mcg of vitamin D3 (2,000 IU) reduced the risk of being diagnosed with ***invasive* cancer**, compared to placebo group, by 24% and, if combined with home strength training (30 minutes three times per week involving sit-to-stand repetitions, balancing on one leg, use of resistance bands, and steps) by 44%. Among participants who were not given vitamin D but omega-3s instead (1 gram of algal oil providing about 167 mg of EPA and 333 mg of DHA per day), risk of invasive cancer was decreased by 30%, and by 48% if combined with strength training. Supplementing with both vitamin D and omega-3s decreased risk by 47%, while combining these with strength training had the greatest impact, decreasing the risk of an invasive cancer by 61%. Blood levels of vitamin D at the end of the study were, unfortunately, not reported. The incidence of invasive cancer, overall, was 3.8% (81 total cases). As possible mechanisms for the benefits, the study authors cite preliminary research that vitamin D can downregulate growth hormones and suppress cancer cell proliferation, omega-3s can inhibit cancer cell formation, and exercise (of at least moderate intensity) can inhibit cancer cell proliferation and induce cancer cell death (Bischoff-Ferrari, Front Nutr 2022).

An analysis of 13 trials that included people with and without vitamin D deficiency (baseline levels of 25(OH)D ranged from 15 to 33 ng/mL) showed that supplementing with vitamin D (400 to 4,000 IU daily, 20,000 IU weekly, or 500,000 IU yearly) did not reduce the **incidence of total cancer** over 3- to 10-year follow-up periods, regardless of dosing strategy (i.e., small daily doses vs. large, infrequent doses). However, among studies that evaluated *daily* vitamin D supplementation (rather than large, infrequent dosing), there was a 24% reduced risk of total cancer among *normal weight* individuals, regardless of baseline vitamin D levels. Daily vitamin D supplementation

was also shown to reduce the risk of cancer mortality by 42% among those of normal weight, but there was no reduction of risk among those who were overweight or obese. A reason why large, infrequent dosing does not appear to be beneficial is that these large doses may be rapidly cleared from circulation (Keum, Br J Cancer 2022).

Other studies have not demonstrated a reduction in cancers from taking vitamin D supplements. For example, a large 4-year placebo-controlled study of post-menopausal women in rural Nebraska found that giving 2,000 IU daily of vitamin D3 and 1,500 mg of calcium (as 3 doses of 500 mg) did not significantly lower the risk of cancer. However, a weakness of this study is that the women were generally not deficient in vitamin D to start — their blood serum levels averaged 32 ng/mL (rising to 44 ng/mL in the treatment group). In fact, most of the women (including those in the placebo group) were already taking vitamin D supplements before the study and were allowed to continue during the study, with average daily intake of around 800 IU (Lappe, JAMA 2017). Similarly, a study of more than 5,000 older adults in New Zealand found that giving high-dose vitamin D (200,000 IU followed by monthly doses of 100,000 IU) for 2.5 to 4.2 years had no impact on cancer incidence compared to placebo treatment. However, most people did not start the study deficient in vitamin D (average blood level was 26.5 ng/mL). Vitamin D treatment raised levels by more than 20 ng/mL (Scragg, JAMA Oncology 2018). Also, a study among more than 21,000 people (age range 60 to 85) in Australia, most of whom were *not* vitamin D deficient, found that receiving 60,000 IU of vitamin D per month (equivalent to about 2,000 IU/day) for 5 years did *not* reduce the incidence of **any cancer**, including **melanoma**, **colorectal**, **lung**, **breast**, or **prostate cancers**, compared to placebo (Neale, J Steroid Biochem Mol Biol 2025).

An unusual report published in 2016 suggests that, for white women aged 55 years and older, vitamin D levels at or above 40 ng/mL, as compared to levels below 20 ng/mL, are associated with greater than a 65% reduction in risk of all invasive cancers combined, excluding skin cancer. This study, however, has several weaknesses including the fact that it was based on pooled data from two unrelated studies, one of which, run by the group GrassrootsHealth (which derives revenue from vitamin D home tests), was based entirely on a self-selected group of women who chose to maintain relatively high levels of vitamin D and self-reported their health status via a questionnaire. While the data indicated much lower rates of cancers (predominantly breast cancer) at increasing mean levels of vitamin D, the greatest decrease was seen as mean levels increased from below 20 ng/mL into the high 30s with no significant benefit indicated above that level. In addition, potential adverse effects were not assessed (McDonnell, PLOS ONE 2016).

A small but well-controlled study among 150 palliative care cancer patients with low levels of vitamin D (25(OH)D of 20 ng/mL or less) showed that those given 4,000 IU of vitamin D3 oil drops daily for 12 weeks increased their dose of fentanyl (an opioid pain medicine) at a slower rate compared to those receiving placebo (about 0.56 mcg *less* fentanyl/hour per week), suggesting modestly reduced pain. Patients receiving vitamin D also reported less fatigue as measured by the Edmonton Symptom Assessment System (ESAS) scale, although not on a different scale. There was no between-group difference in antibiotic use or quality of life. Average 25(OH)D increased from about 14 ng/mL to 32 ng/mL among those in the vitamin D group (Frankling, Cancers 2021).

Colorectal cancer

A moderately decreased risk of developing **colorectal cancers**, specifically, has been demonstrated with higher vitamin D levels as well as with higher vitamin D intakes (Ma, J Clin Oncol 2011). An analysis of data from two large studies of health professionals found higher vitamin D levels to be associated with a much lower risk of developing a subtype of colorectal cancer in which there is extensive immune cell infiltration within the tumor — perhaps explained by vitamin D's effects on the immune system. Compared to people with the lowest vitamin D blood levels (around 19 ng/mL), those with mid-range levels (around 27.9 ng/mL) had only 33% of the risk of developing this type of tumor, and those with the highest vitamin D levels (around 37.4 ng/mL) had just 10% of the risk (Song, Gut 2015). A review of 17 studies compared the risk of colorectal cancer in people with varying blood levels. It found that, compared to those having levels of 20 to <25 ng/mL, the risk was 31% *higher* when levels were below 12 ng/mL, but 19% *lower* at 30 to <35 ng/mL and 27% *lower* at 35 to <40 ng/mL, although there was no statistically significant risk reduction at 40 ng/mL or greater (McCullough, J Natl Cancer Inst 2018).

In seeming contrast to this, a large, multi-year study in the U.S. found that daily supplementation with vitamin D3 (1,000 IU) and/or calcium (1,200 mg) did not reduce the risk of developing new precancerous colorectal polyps (adenomas) among people who had adenomas removed in the past. There was no statistically significant difference in the occurrence of adenomas between those who were or were not given the supplements. However, the vast majority of subjects began the study with adequate blood levels of vitamin D (averaging 24 to 25 ng/mL); in fact, anyone with a level below 12 ng/mL was excluded from the study (Baron, NEJM 2015). These findings, therefore, may not apply to people with vitamin D levels that are inadequate, i.e., under 20 ng/mL. In fact, a large study that followed men and women in the U.S. and Canada with previously untreated advanced or metastatic colorectal cancer for a median of 5.6 years found that those who started chemotherapy with vitamin D blood levels of at least 24.1 ng/mL were 19% less likely to have disease progression and 34% less likely to die in comparison to those who were deficient in vitamin D (< 10.8 ng/mL) at the start of treatment (Yuan, Clin Cancer Res 2019).

Giving people in Japan who were treated for cancers of the **digestive tract** (mainly colorectal, gastric, or esophageal cancers) 2,000 IU of vitamin D daily for 5 years did *not* improve relapse-free survival (Urashima, JAMA 2019). *However*, further analysis showed that among the 36% of patients who were positive for biomarkers of a mutation of the p53 gene, vitamin D supplementation *reduced the risk of relapse or death* within 5 years after the study ended to 30.6% -- significantly lower than the 80.9% among those who had been given a placebo (Kanno, JAMA Open 2023). It should be noted that, at the start of the study, none of the participants had been supplementing with vitamin D and a large portion of them had insufficient levels of vitamin D (50% were below 21 ng/mL); during the study, this level increased to 41 ng/mg on average for those given vitamin D but did not change in those given placebo. The p53 gene is a tumor suppressor gene, and mutations of it are associated with increased cancer risk, while vitamin D receptors on cells help control cancer when activated with vitamin D. It's possible that having adequate vitamin D helped counteract the loss of normal tumor suppression in people with p53 gene mutations (Holick, JAMA Open 2023).

Breast cancer

Vitamin D supplementation may improve breast cancer prognosis for women with low vitamin D levels, but it doesn't seem to benefit women with adequate levels. It is uncertain if vitamin D supplementation helps reduce the risk of breast cancer.

A study of 1,666 women (average age 59) with **breast cancer** found that those with higher vitamin D blood levels around the time of diagnosis had the highest overall survival rates over an average 7 years of follow up. Nineteen percent of women with the lowest levels of vitamin D (under 17 ng/mL) died during the follow up period, while only about 14% died among those with higher levels. After accounting for differences in tumors and treatments, it was calculated that women with vitamin D levels of 17 to 25 ng/mL and those with more than 25 ng/mL were, respectively, 22% and 28% less likely to have died than women with the lowest levels. The reduction in risk associated with vitamin D was greatest for premenopausal women. Women with lowest blood levels of vitamin D at the time of diagnosis were more likely to have the most advanced-staged tumors (Yao, JAMA Oncol 2016). Somewhat similarly, an analysis in 2014 of five clinical studies found that women who had the highest vitamin D blood levels at the time of breast cancer diagnosis were twice as likely to survive during the studies (which lasted 5 to 20 years) as women with the lowest vitamin D levels (Mohr, Anticancer Research 2014). Due to differences in the studies analyzed, the "low" vitamin D groups included women with less than 14 to 30 ng/mL of vitamin D while the "high" groups included those with more than 22 to 32.4 ng/mL. While this association between vitamin D levels and mortality with breast cancer is not proven to be "cause-and-effect," there is no scientific reason to believe that breast cancer would cause a decrease in vitamin D, suggesting a likely beneficial effect of vitamin D.

Interestingly, there is some evidence that certain chemotherapy regimens might lower blood levels of vitamin D, and consequently, supplementing with vitamin D during chemotherapy might be beneficial. A study in Brazil among 75 postmenopausal women (average age 56) with breast cancer and low vitamin D levels showed that taking 2,000 IU of vitamin D daily for 6 months, along with chemotherapy, raised vitamin D levels to 28 ng/mL and increased the complete response rate (43% vs. 24%) compared to placebo, which showed a slight, although insignificant, reduction in vitamin D levels compared to baseline (Omodei, Nutr Cancer 2025).

On the other hand, vitamin D supplementation may not improve breast cancer prognosis among women with already adequate levels. A randomized, placebo-controlled study in Canada among 80 women with newly diagnosed invasive breast cancer and generally sufficient blood levels of vitamin D (average 29 ng/mL) found that very high-dose vitamin D3 (40,000 IU) taken daily for two to six weeks before breast cancer surgery *did not* slow tumor growth. Blood levels increased to about 98.5 ng/mL (an *extremely* high level) in those who took high-dose vitamin D, and decreased somewhat, to 25 ng/mL, in those who did not. Women who took high-dose vitamin D experienced more fatigue than those who took a placebo, although no serious adverse effects were reported in this short-term study (Arnaout, Breast Cancer Res Treat 2019).

An analysis of data pooled from three studies concluded that higher vitamin D blood levels "... were associated with a dose-response decrease in breast cancer risk with concentrations ≥ 60 ng/mL being most protective." *However*, this is a potentially unsafe level and the conclusion is dubious. The analysis was primarily based on data from just one of the studies, known as the GrassrootsHealth study, which, unlike the other two, was not randomized or placebo-controlled and was based on self-reported health information from a self-selected group of people interested in vitamin D. Not surprisingly, it was also the only study that had a significant number of participants with vitamin D levels higher than 40 ng/mL (McDonnell, PLOS One 2018).

Bladder cancer

A study in Spain found that lower levels of vitamin D in the blood were associated with higher risks of **bladder cancer**. Compared to people with vitamin D levels of 30 ng/mL or above, the risk of bladder cancer was 83% higher among those with levels under 10 ng/mL, 67% higher among those with levels of 10 up to 15 ng/mL, and 63% higher among those with levels of 15 up to 20 ng/mL. There was no statistically significant difference in risk, however, between those with levels of 20 up to 30 ng/mL compared to those above 30 ng/mL. (Amaral, JNCI 2012). Even greater increases were found with the risk of *metastatic* bladder cancer.

Pancreatic cancer

Laboratory studies suggest that vitamin D may inhibit **pancreatic cancer** cell growth and a review of five large epidemiologic studies concluded that higher levels of serum vitamin D were associated with a lower risk of developing pancreatic cancer (Wolpin, Cancer Epidemiol Biomarkers Prev 2011). Compared to people whose serum vitamin D levels were less than 20 ng/mL, the risk of developing pancreatic cancer over the following 12 to 18 years was 25% lower among those with levels of 20 mg to 29 ng/mL, and 29% lower among those with levels above 30 ng/mL.

Prostate cancer

Vitamin D inhibits **prostate cancer** cells in laboratory studies. Whether or not vitamin D supplementation actually reduces the risk of prostate cancer is not known, but some studies do suggest an association between vitamin D levels and prostate cancer risk. For example, a large study in the U.S. found that *both low and high* vitamin D concentrations in the blood to be associated with increased risk of prostate cancer, particularly high-grade prostate cancer. The middle "sweet spot" associated with the lowest risk (about half the risk of the higher or lower levels) was between 23 ng/mL and 29 ng/mL, leading the researchers to write that the optimal range "for prostate cancer prevention may be narrow" (Kristal, Canc Epi Biomark, Prev 2014). This finding is somewhat consistent with a smaller study of men in Chicago undergoing radical prostatectomy (due to indications of possible cancer), in which those found *not* to have advanced cancer had a median blood level of 27.0 ng/mL, which was only slightly higher than that of men *with* advanced cancer (22.7 ng/mL). However, the study found that men with advanced cancer were more likely to be Black, and the Black men were more likely to have lower levels of vitamin D (as seen in other studies), so when the results were analyzed just among Blacks or among whites, there was no longer an association between vitamin D levels and advanced prostate cancer (Nyame, J Clin Oncol 2016).

A study of men aged 40 to 79 in the U.S. undergoing their first prostate biopsy for potential cancer, found that, in African American men, having a vitamin D level below 20 ng/mL was associated with increased odds of the biopsy showing prostate cancer. In addition, among both European American and African American men, having a level below 12 ng/mL was associated with a higher grade and stage of prostate cancer (Murphy, Clin Cancer Res, 2014).

A study of male smokers in Finland concluded that "men with higher vitamin D blood levels are at increased risk of developing prostate cancer," but this assertion has been called misleading since the risk increased only among men with calcium intakes of 1,338 mg per day or greater — an intake that substantially exceeds the recommended intake for adult men (1,000 mg). Increased calcium intake itself is a potential risk factor for prostate cancer (Albanes, Canc Epidemiol Biomarkers Prev 2011; Schwartz, Canc Epidemiol Biomarkers Prev 2012).

Interestingly, high-dose vitamin D supplementation may reduce bone loss during **androgen deprivation therapy** for prostate cancer, particularly at bone sites with already low bone mineral density. A small study among 52 men with prostate cancer who were on androgen deprivation therapy showed that receiving high-dose vitamin D supplementation (50,000 IU of vitamin D3 once weekly) for 24 weeks resulted in significantly less bone density loss in the hip versus placebo (-1.5% vs. -4.1%) and less loss in the neck of the femur (-1.7% vs. -4.4%), but not the upper thigh or spine — although those two areas had greater density to start. However, the benefits of vitamin D were only significant for those whose vitamin D levels had been below 27 ng/mL at the start of the study, and not those whose levels were above 27 ng/mL. Participants in both groups also received a daily multivitamin providing 800 IU/day of vitamin D and 210 mg/day of calcium, plus a separate calcium supplement providing 800 mg/day. Hypercalcemia was the most common adverse event, but there was no difference in the number of these events between the vitamin D and placebo groups (Peppone, Cancer 2024).

Skin cancer

A study of people with **melanoma** in whom lesions had recently been removed found no difference in disease-free *survival* with or without vitamin D supplementation (100,000 IU every 50 days) over a course of three years, despite that fact that half the participants started the study with a vitamin D level of 18 ng/mL or lower (Johansson, Nutrients 2021). It should also be noted that taking single, very-high doses of vitamin D (as was used in this study) has been associated with adverse effects, and in many cases, taking lower, daily doses may be preferable.

Advanced solid tumors

In a study of 339 people with **advanced solid tumors** (such as lung and kidney cancers) in Italy who generally had low blood levels of vitamin D (average: 13 ng/mL), supplementing their medical treatment (checkpoint inhibitors) with vitamin D reduced the risk of death by 33% and the risk of treatment discontinuation by 28% compared with not supplementing with vitamin D. Vitamin D dosage depended on initial level of deficiency, beginning with very large doses (cumulative dose: 300,000 to 1,000,000 IU) given over one month prior to starting medical therapy and continuing at a lower dose (820 IU to 2,000 IU daily) for several months during medical therapy (Bersanelli, Cancer Immunol Immunother 2023).

Overall mortality

A review of studies involving vitamin D concluded that supplementation with vitamin D_3 reduced overall mortality among older adults significantly by 11%, while vitamin D_2 had no overall effect (Chowdhury, BMJ 2014). The review also found that, in the U.S., about 13% of all deaths could be attributable to "suboptimal" vitamin D levels, which is even greater than the risk of death associated with physical inactivity. The review did not define exactly when, or how much, vitamin D is most effective, but you can find sensible guidelines in the Summary, above.

A study that followed more than 300,000 healthy adults in the UK for a median of 8.9 years found that the risk of dying during that period decreased as vitamin D blood levels increased to 24 ng/mL (or to 19 ng/mL for death from cancer) and then leveled off (Fan, J Clin Endocrinol Metab 2020).

Similarly, a study that followed 1,970 European men (ages 40 to 79) for an average of 12.3 years found that those with vitamin D blood levels (i.e., *total* 25-hydroxyvitamin D levels) less than 9.3 ng/mL (i.e., severely deficient) had an 83% increased mortality risk compared to those with highest levels (Antonio, eECE 2020).

On a similar note, an analysis of data from 3,509 patients recovering from noncardiac surgery at the Cleveland Clinic found that those with higher levels of vitamin D in their blood were less likely to experience serious post-operative complications, including death (Turan, Anesth Analg 2014). In fact, compared to the level of complications in patients with serum vitamin D levels below 13 ng/mL, the risk of

having serious complications fell to 65% when vitamin D levels were between 13 to 20 ng/mL, to 53% at levels between 20 and 27 ng/mL, and to 44% at levels between 27 and 36 ng/mL. Interestingly, at levels above 36 ng/mL, the relative odds of complications did not fall further and rose slightly, to 49%, consistent with other studies that have shown a reversal in benefits with vitamin D levels above approximately 35 ng/mL. The researchers suggest a trial be conducted in which vitamin D supplementation is given preoperatively.

Improving iron status

Observational studies have linked vitamin D deficiency with increased risk of iron deficiency (Al-Taiar, BMC Pregnancy Childbirth 2025; Mogire, Nutrients 2022) and there is evidence that vitamin D can may improve iron absorption by lowering blood levels of hepcidin, a hormone that reduces iron absorption from the small intestines (Smith, Clin Nutr 2017).

However, vitamin D supplementation may raise iron levels only in people with low blood levels of both vitamin D *and* iron, and it may not help treat iron-deficiency anemia. A study in Malaysia among 39 premenopausal women (average age 25) with low iron status (average ferritin concentration: 10.2 ng/mL; normal range: 13 to 15 ng/mL) and low blood levels of vitamin D (13 ng/mL) showed that getting 4,000 IU (100 mcg) of vitamin D3 once daily for 8 weeks significantly increased blood levels of vitamin D (to 43.5 ng/mL) and increased ferritin levels by 2.2 ng/mL, and both of these improvements were significant compared to the placebo group. However, there were no significant changes in hemoglobin levels or the red blood cell counts (Suhaimi, J Acad Nutr Diet 2024).

Quality Concerns and Tests Performed:

Like other supplements, neither the FDA nor any other federal or state agency routinely tests vitamin D supplements for quality prior to sale. However, quality issues can include the following:

- **Labeled Amount** Does the product really contain the labeled amount of vitamin D and other key ingredients?
- **Purity** Vitamin D supplements for bone health often include calcium as an ingredient. Calcium may potentially be contaminated with heavy metals such as lead, arsenic and cadmium. In children, infants, and fetuses, even low levels of lead can adversely affect neurobehavioral development and cognitive function. In adults, lead at somewhat higher levels can cause elevated blood pressure, anemia, and adversely affect the nervous and reproductive systems. Lead is of particular concern during pregnancy as the mother can deliver it to the fetus. Arsenic is a carcinogen and can damage organs. Cadmium is a probable carcinogen (i.e., cancer-causing agent), can be toxic to the kidneys, can soften the bones, causing bone pain, and may affect fetal development.
- **Ability to Break Apart for Absorption** For a tablet to be most useful, it must fully disintegrate prior to leaving the stomach, delivering its contents for absorption in the gut. Some tablets are not properly made and can pass through your body completely or partially intact, depriving you of its ingredients. Remnants of such products are sometimes found in the stool. This happens, for example, when a tablet is too tightly compressed (too "hard") or is too thickly coated.
- **Side Effects at Suggested Dosage** — ConsumerLab.com reviewed the levels of vitamin D, magnesium, and calcium to determine if any product provided doses high enough to carry a risk of adverse side effects. Those that exceeded Tolerable Upper Intake Levels (ULs) are footnoted.

ConsumerLab.com, as part of its mission to independently evaluate products that affect health, wellness, and nutrition, purchased vitamin D supplements sold in the U.S. and Canada and tested them to determine whether they 1) possessed the claimed amount and form of vitamin D 2) were able to disintegrate fully to be available for absorption and, 3) if they listed minerals and/or whole herbs, were free from unacceptable levels of lead, arsenic, cadmium, and mercury (see Testing Methods and Passing Score).

What CL Found:

[**Update: (7/30/24)**: Twelve products were added to this Review that are combinations of vitamin D with **calcium**, **magnesium**, **vitamin K**, and/or **boron** that also appear our separate Reviews of those nutrients.]

Most products were found to contain their listed amounts of vitamin D, but two contained much more, posing a health risk, and were ***Not* Approved**:

- Our tests revealed that a 2-drop serving of ***Biotics Research Bio-D-Mulsion Forte*** contained *nearly twice* its listed 100 mcg (4,000 IU) of vitamin D and, instead, provided 195 mcg or 7,789.4 IU. This is way over the upper tolerable intake level for vitamin D, which is 100 mcg (4,000 IU) for people ages 9 and above, and lower for younger children. A person taking a 2-drop serving would, unknowingly, put themselves at risk of hypercalcemia (too much calcium in the blood) and other problems associated with having **too much vitamin D**, such as bone fractures. This failure was confirmed in a second independent laboratory.

- Similarly, we found that *Sports Research D3 + K2* contained *much more vitamin D* than listed -- 193 mcg (7,720 IU) instead of 125 mcg (5,000 IU) -- despite providing its listed amount of vitamin K. This issue was confirmed in a second independent laboratory. While some overage of vitamin D is acceptable, particularly with lower doses of vitamin D, this is a very high-dose product to begin with: Even at its labeled amount of 125 mcg, it was above the Tolerable Upper Intake Level (UL) for vitamin D, There is an increasing risk of **hypercalcemia** when exceeding the UL.

In addition, *Life Extension Bone Restore Calcium Supplement with Vitamin K2* was ***Not* Approved** because we found it to contain *only 80.8% of its listed amount of vitamin K2* as trans MK-7 (a deficiency confirmed in second independent laboratory), although it still provided a substantial dose of vitamin K and correct amounts of other key ingredients.

The fact that *Life Extension* contained less vitamin K than listed but had the correct amounts of other key ingredients may be due to known issues with the purity of MK-7 (i.e., how much is in the active "trans" form rather than the inactive "cis" form) and instability of MK-7 when it is combined with large amounts of minerals such as calcium and magnesium, as has been suggested by other studies (Orlando, Molecules 2019; Szterk, Food Chem 2018). These issues may also help explain why, in our Review in 2022, we found that *Jarrow Formulas BoneUp* contained only 30.7% of its claimed vitamin K2 (as MK-7) (4.6 mcg instead of 15 mcg), despite containing its amounts of calcium, magnesium, boron, and vitamin D.

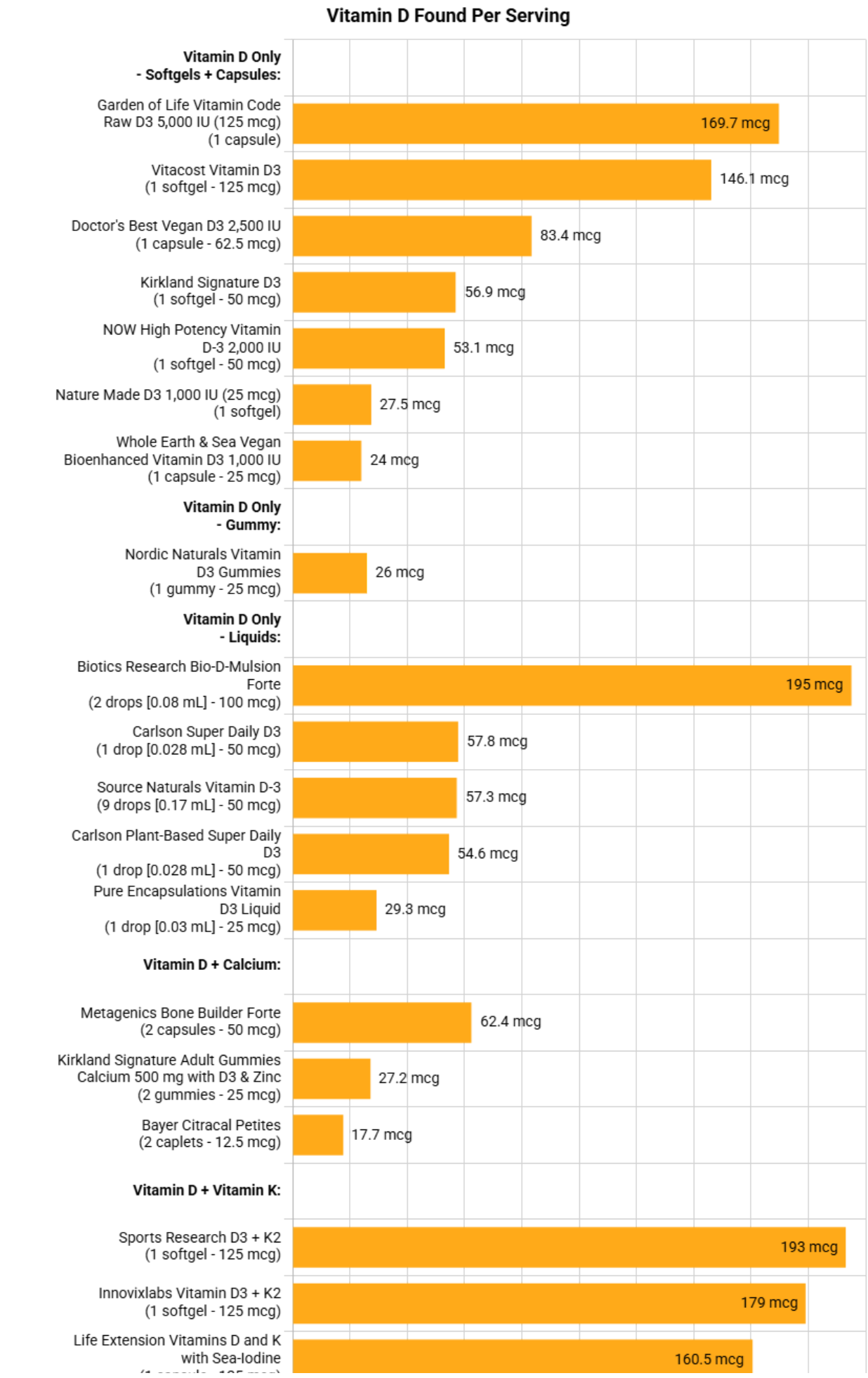
Range of Dose

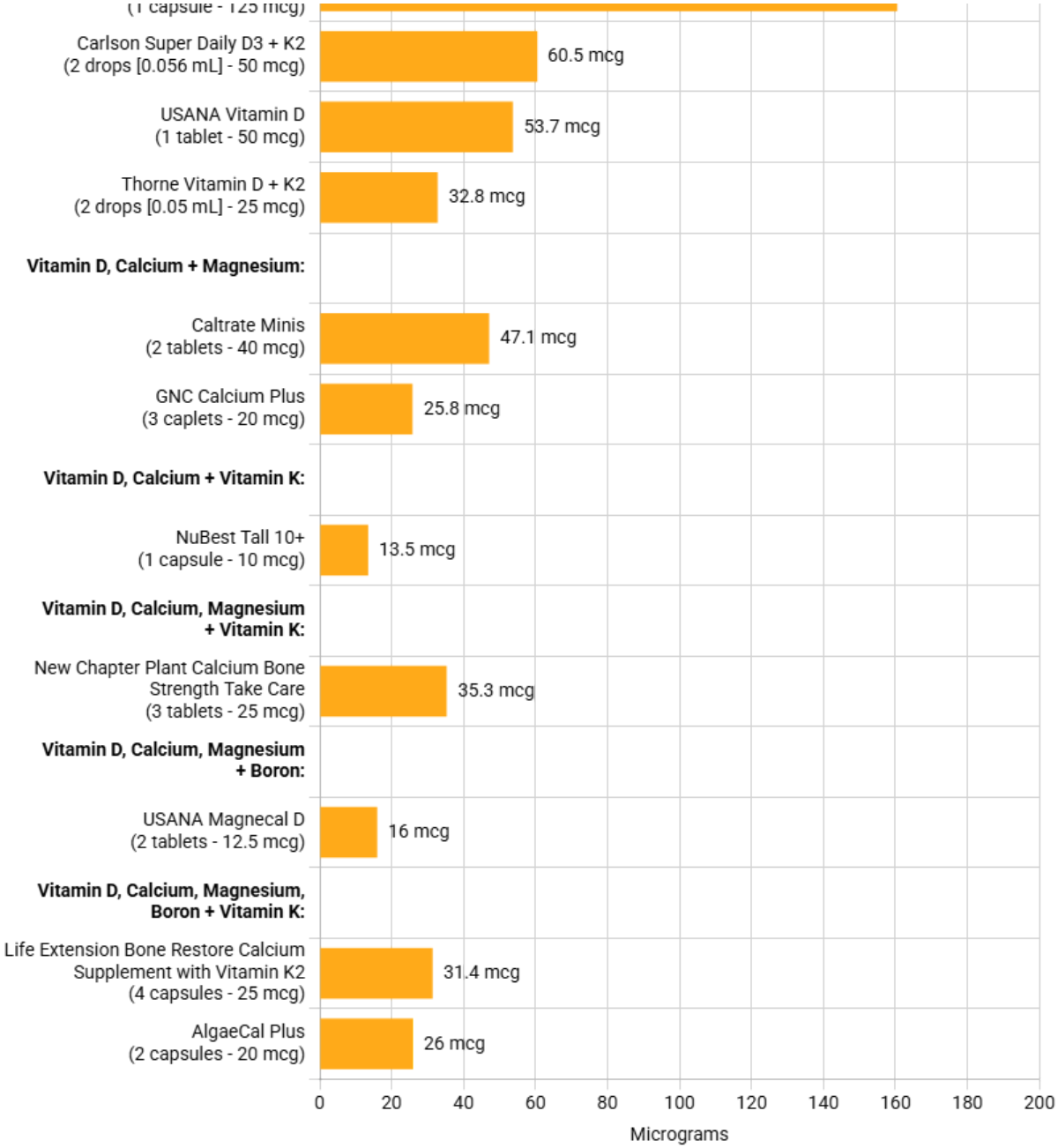
Nearly all the products contained somewhat more vitamin D than listed, although this was generally within an acceptable margin other than for *Biotics Research* and *Sports Research D3 + K2*, as discussed above. *Whole Earth & Sea* which had slightly less vitamin D than listed, but within an acceptable margin.

Be aware that the amount of vitamin D found in a single serving of each supplement ranged across products:

- On the lower end were products with around 25 mcg (1,000 IU) of vitamin D, which is already higher than the recommended daily intake levels (15 mcg or 600 IU for everyone other than infants, or 20 mcg or 800 IU for adults over 70). Two products had slightly lower amounts per serving (13.5 mcg in *NuBest Tall 10+* and 16 mcg in *USANA Magnecal D*), but *USANA Magnecal D* suggested *two servings* daily, putting it above the daily requirements for vitamin D, but also above the upper tolerable intake level for magnesium, above which there may be a laxative effect.

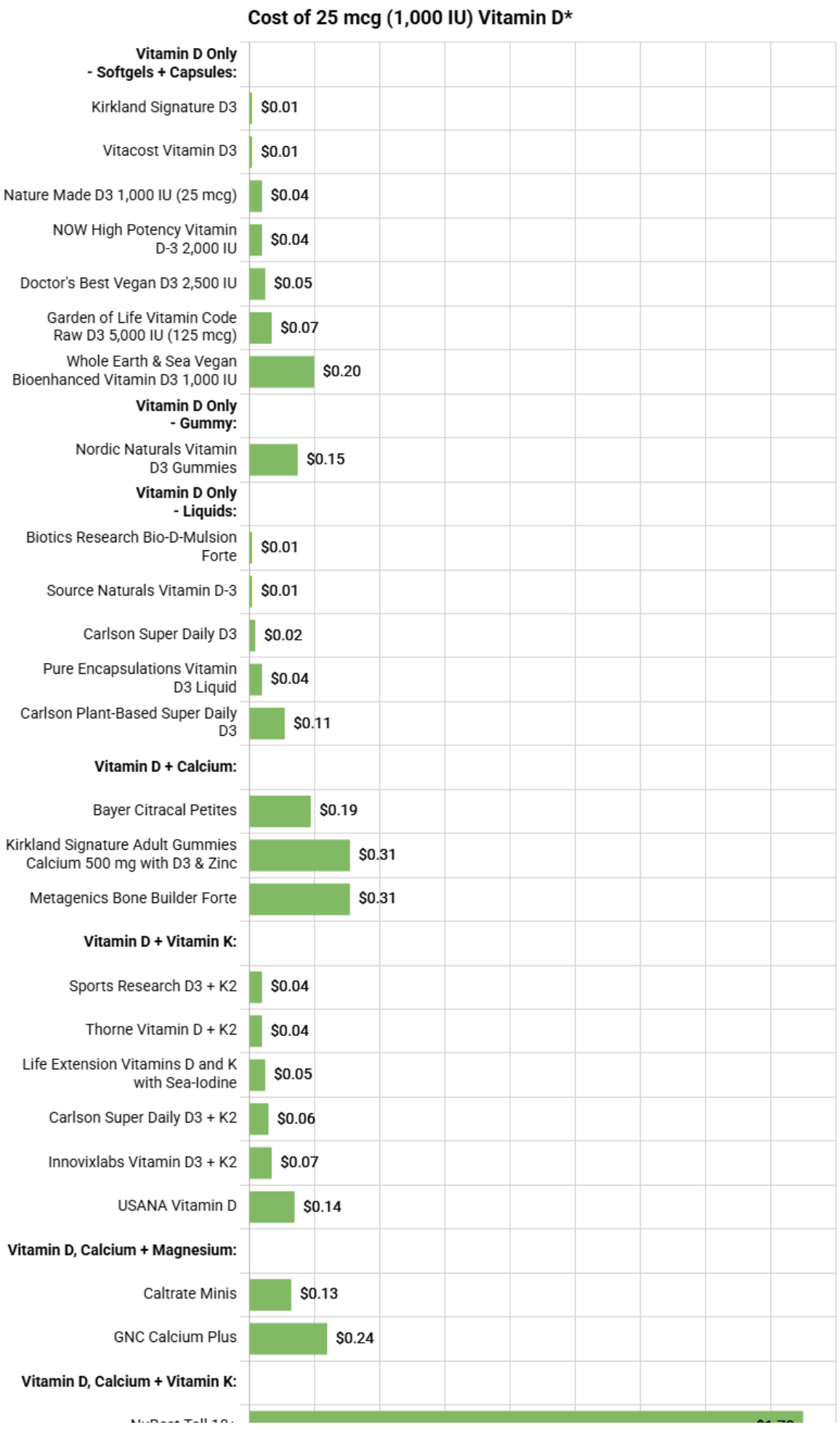
- At the upper end were three products that provided 146 mcg (5,840 IU) or more -- which is not only far above the general daily requirements but also above the upper tolerable intake level, above which there is increasing risk of an adverse effect and, typically, is only needed to treat deficiencies. These were products from *Vitacost*, *Garden of Life*, and, as noted earlier, *Biotics Research* and *Sports Research D3 + K2*.


Vitamin D Found Per Serving
Vitamin D Only - Softgels + Capsules:
Garden of Life Vitamin Code Raw D3 5,000 IU (125 mcg) (1 capsule)
169.7 mcg
Vitacost Vitamin D3 (1 softgel - 125 mcg)
146.1 mcg
Doctor's Best Vegan D3 2,500 IU (1 capsule - 62.5 mcg)
83.4 mcg
Kirkland Signature D3 (1 softgel - 50 mcg)
56.9 mcg
NOW High Potency Vitamin D-3 2,000 IU (1 softgel - 50 mcg)
53.1 mcg
Nature Made D3 1,000 IU (25 mcg) (1 softgel)
27.5 mcg
Whole Earth & Sea Vegan Bioenhanced Vitamin D3 1,000 IU (1 capsule - 25 mcg)
24 mcg
Vitamin D Only - Gummy:
Nordic Naturals Vitamin D3 Gummies (1 gummy - 25 mcg)
26 mcg
Vitamin D Only - Liquids:
Biotics Research Bio-D-Mulsion Forte (2 drops [0.08 mL] - 100 mcg)
195 mcg
Carlson Super Daily D3 (1 drop [0.028 mL] - 50 mcg)
57.8 mcg
Source Naturals Vitamin D-3 (9 drops [0.17 mL] - 50 mcg)
57.3 mcg
Carlson Plant-Based Super Daily D3 (1 drop [0.028 mL] - 50 mcg)
54.6 mcg
Pure Encapsulations Vitamin D3 Liquid (1 drop [0.03 mL] - 25 mcg)
29.3 mcg
Vitamin D + Calcium:
Metagenics Bone Builder Forte (2 capsules - 50 mcg)
62.4 mcg
Kirkland Signature Adult Gummies Calcium 500 mg with D3 & Zinc (2 gummies - 25 mcg)
27.2 mcg
Bayer Citracal Petites (2 caplets - 12.5 mcg)
17.7 mcg
Vitamin D + Vitamin K:
Sports Research D3 + K2 (1 softgel - 125 mcg)
193 mcg
Innovixlabs Vitamin D3 + K2 (1 softgel - 125 mcg)
179 mcg
Life Extension Vitamins D and K with Sea-Iodine
160.5 mcg



Cost

Vitamin D itself is a very inexpensive ingredient. The cost to get a 25 mcg (1,000 IU) dose can be pennies, or even just one cent from some products, particularly liquids, as shown below. Extra ingredients and special formulations, such as gummies, as well as products with vegan, vegetarian, or all-natural ingredients, tend to cost more, with some costing more than $1 per day.


Cost of 25 mcg (1,000 IU) Vitamin D*
Vitamin D Only - Softgels + Capsules:
Kirkland Signature D3
$0.01
Vitacost Vitamin D3
$0.01
Nature Made D3 1,000 IU (25 mcg)
$0.04
NOW High Potency Vitamin D-3 2,000 IU
$0.04
Doctor's Best Vegan D3 2,500 IU
$0.05
Garden of Life Vitamin Code Raw D3 5,000 IU (125 mcg)
$0.07
Whole Earth & Sea Vegan Bioenhanced Vitamin D3 1,000 IU
$0.20
Vitamin D Only - Gummy:
Nordic Naturals Vitamin D3 Gummies
$0.15
Vitamin D Only - Liquids:
Biotics Research Bio-D-Mulsion Forte
$0.01
Source Naturals Vitamin D-3
$0.01
Carlson Super Daily D3
$0.02
Pure Encapsulations Vitamin D3 Liquid
$0.04
Carlson Plant-Based Super Daily D3
$0.11
Vitamin D + Calcium:
Bayer Citracal Petites
$0.19
Kirkland Signature Adult Gummies Calcium 500 mg with D3 & Zinc
$0.31
Metagenics Bone Builder Forte
$0.31
Vitamin D + Vitamin K:
Sports Research D3 + K2
$0.04
Thorne Vitamin D + K2
$0.04
Life Extension Vitamins D and K with Sea-Iodine
$0.05
Carlson Super Daily D3 + K2
$0.06
Innovixlabs Vitamin D3 + K2
$0.07
USANA Vitamin D
$0.14
Vitamin D, Calcium + Magnesium:
Caltrate Minis
$0.13
GNC Calcium Plus
$0.24
Vitamin D, Calcium + Vitamin K:

* Costs based on amounts found.

Top Picks:

Among Approved products, ConsumerLab.com chose several as ***Top Picks*** (see below) that passed ConsumerLab's tests of quality, provided a reasonable dose, offered good value (i.e., a favorable price), and were convenient to use.

For reference, keep in mind that the recommended daily allowance of vitamin D is only 10 mcg (400 IU) for infants, 15 mcg (600 IU) per day for ages 1 to 69, and 800 IU if you're over 70. The established daily Tolerable Upper Intake Level (the "upper limit") for adults is 4,000 IU per day and there are risks from getting too much vitamin D — it's probably best not to take more than 2,000 IU per day (see How Much Is Too Much and Cautions and Concerns for more information).

Vitamin D-Only

Overall Top Pick and *Top Pick* Among *Liquids*:

Source Naturals Vitamin D-3 liquid drops ($17.55 for 4 fl oz, providing 695 9-drop servings of 50 mcg/2,000 IU — and we found a bit more — 57.3 mcg/2,292 IU). This is an excellent choice because you can easily adjust your dose to suit your current needs and those of other family members, and each dose is inexpensive. [**Safety Note**: We do *not* recommend use of this product with **infants or toddlers**. The FDA suggests that a full dropper for children should not hold more than 400 IU (10 mcg) of vitamin D to avoid overdosing.]

One drop of *Source Naturals* promises 5.6 mcg/222 IU of vitamin D3 for just a fraction of a cent. If you need a higher dose, you can get 50 mcg/2,000 IU from 9 drops (which is the suggested daily serving size on the label) for just 3 cents. The drops have a mild orange flavor and can be added to food or beverages — preferably consumed as part of a meal containing fats or oils to aid vitamin D absorption (as would be the case with any vitamin D supplement).

We prefer *Source Naturals* over the other liquids because of its lower dose of vitamin D per drop (versus 1,000 or 2,000 IU per drop) and its traditional bulb-dropper that allows you to more easily measure out the number of drops than drop-top bottles. Just be aware that 9 drops is just a small part of the dropper, so fill the dropper no more than ¼ of the way up to better control the flow when dispensing.

As vitamin D supplements may gradually lose potency after they are opened, consider refrigerating your vitamin D supplement (to slow the loss) if you won't use it up before its listed expiration date (usually about 2 years from the date of manufacture). This will also slow spoilage of the oil (such as medium chain triglycerides) used in the liquids. One bottle of *Source Naturals* could last *more than 5 years* if you're only using, for example, 3 drops (667 IU) daily. Also consider storing this, or any liquid vitamin D, in a small tray, as any excess oil on the lip of the bottle may slowly spill down the sides.

Top Picks Among Pills:

- Moderate Dose (25 mcg or 1,000 IU): ***Nature Made D3 1,000 IU (25 mcg)*** (we found slightly more — 1,098 IU or 27.5 mcg) is just 4 cents per softgel (which is very small and easy to swallow) ($12.20 for 300 softgels). Our previous *Top Pick* in this category in 2022 was *Spring Valley Vitamin D3 25 mcg* (1,000 IU) which is very similar and costs a penny less per softgel ($7.80 for 450 softgels) but was not tested this year due to lack of popularity among CL members. *Nature Made* softgels are made from gelatin and the vitamin D is likely derived from lanolin (from sheep's wool), so if you are vegan or vegetarian, an alternative (although more expensive) is ***Whole Earth & Sea Vegan Bioenhanced Vitamin D3 1,000 IU*** (we found slightly less — 961.6 IU) for 19 cents per capsule. It is a Canadian product but can be purchased online in the U.S.

- High Dose (50 mcg or 2,000 IU): If you want 50 mcg (2,000 IU) of vitamin D, you can consider the liquid discussed above or a single, very small softgel of ***Kirkland Signature D3 50 mcg*** (we found slightly more — 56.9 mcg) for just 2 cents. Our previous *Top Pick* in this category in 2022 was *Member's Mark [Sam's Club] Vitamin D-3 2000 IU* (2 cents) but it was not tested this year due to lack of popularity among CL members. The *Kirkland* softgels are very similar to *NOW Vitamin D-3 2,000 IU*, but *NOW's* capsules cost a little more. If you are vegan and you want a somewhat higher dose, ***Doctor's Best Vegan 2500 IU*** (we found somewhat more — 3,336 IU) is a good option, but costs 17 cents per veggie capsule. Its vitamin D is from lichen.

- Very High Dose (100-125 mcg or 4,000-5,000 IU): ***Vitacost Vitamin D3 125 mcg*** (5,000 IU) medium sized softgels each provide 5,000 IU of vitamin D (we found somewhat more — 5,844 IU) for just 3 cents each. *Be aware that these exceed the safe Tolerable Upper Intake Level for vitamin D of 4,000 IU*. If you want a vegetarian product, you'll need to pay more: ***Garden of Life Raw D3 5,000 IU*** (we found somewhat more — 6,789.1 IU) costs 45 cents per vegetarian capsule. It is made with vitamin D3 from yeast culture. These two products were also our *Top Picks* for this category in 2022.

- Extremely High Dose (10,000 IU): This is a potentially dangerous dose and should not be taken more than once every several days. It is best to avoid such a high dose, which should only be considered when a person is known to be severely deficient in vitamin D and unlikely to reliably take a lower-dose daily vitamin D supplement. We have not tested any products with this amount of vitamin D in several years, but, in 2019, we tested one, *Bronson Vitamin D3 10,000 IU*, which was Approved. Each capsule provided 10,000 IU of vitamin D3 for 6 cents.

Top Pick Among Gummies:

We only tested one gummy, ***Nordic Naturals Vitamin D3 Gummies - Great Wild Berry Taste***, and we consider it a *Top Pick* if a gummy is what you want. It claims 25 mcg (1,000 IU) of vitamin D and we found slightly more — 26 mcg (1040.8 IU). It has a nice, sweet, fruity taste, and costs 16 cents per gummy ($18.66/120 gummies). However, we're not a fan of gummies, like this one, because 1) they are more expensive than pills and liquids (15 cents vs as little as 1 cent), 2) they contain sugar and calories (10 Calories per *Nordic Naturals* gummy from 2 grams of sugar), 3) children, and even adults, may consume more than they should because they look and taste like candy, and 4) they are sticky and sugary, so can contribute to cavities and gum inflammation.

Vitamin D and Vitamin K

We have *two Top Picks* for combinations of vitamins D and K, depending on the type of vitamin K you're seeking.

One is ***Thorne Vitamin D + K2***, as it provides a dose of **MK-4** (200 mcg per 2 drop serving for only 5 cents) that should meet vitamin K nutritional requirements, as well as 25 mcg (1,000 IU) of vitamin D — which is somewhat more than the daily adult requirements for vitamin D. Be aware that the amount of MK-4 in *Thorne* is much lower than the 45,000 mcg that appeared to improve bone mineral density and reduce fracture risk in small studies in Asia, but those results have yet to be replicated in larger studies.

If you prefer the **MK-7** form of vitamin K2, then our *Top Pick* is ***Carlson Super Daily D3 + K2***, as 2 drops provides 50 mcg (2,000 IU) of vitamin D (we found about 20% more) and about 45 mcg of vitamin K-2 as MK-7 for 14 cents. Be aware that the evidence of combinations of MK-7 with vitamin D helping with bone density have not be promising (see What It Does — in our Vitamin K Review).

It should be noted that animal research has suggested that *vitamin D may reduce absorption of vitamin K* when taken together, although this effect has not been established in people.

Vitamin D with Calcium and in "Bone Health" Formulas

Vitamin D and Calcium: ***Bayer Citracal Petites*** is our *Top Pick* in the vitamin D and calcium category, as it was in our 2022 Review. It lists 400 mg of calcium (from calcium citrate) and 12.5 mcg (500 IU) of vitamin D per 2-caplet serving for 14 cents. We found somewhat more vitamin D (17.7 mcg) and a little less calcium (375.1 mg), but this is a good boost to calcium intake without being too much and enough vitamin D to boost someone who's a little low in vitamin D. Note that, despite the product name, the caplet size is large, although narrow. (If you live in Canada, *Webber Naturals Calcium Citrate Vitamin D3* was tested by us in 2022 and was another *Top Pick* in this category, offering 300 mg of calcium (from calcium citrate) and 5 mcg (200 IU) of vitamin D for 11 cents.)

If you prefer a gummy (we don't) to get vitamin D and calcium, our *Top Pick* is ***Kirkland Signature (Costco) Adult Gummies***. Each orange- or cherry-flavored, large, sugar-encrusted gummy drop lists 250 mg of calcium and 12.5 mcg (500 IU) of vitamin D3 for about 16 cents -- and we found slightly more calcium and vitamin D than listed. It is made with calcium phosphate, which may not raise calcium levels as well as calcium citrate. Be aware that each gummy claims to provide 3.5 mg of zinc — about 30% of the daily requirement, but well below the daily tolerable upper intake level (UL) of 40 mg for adults.

We are not big fans of gummies for several reasons, including the fact that they typically have added sugar (about a teaspoonful per 2-gummy serving of *Kirkland*) and may be over-consumed as candy, resulting in overdosing. But if gummies are the only way to get a kid or adult who otherwise won't get enough nutrients from foods or non-sweetened supplements to meet the daily requirements, they are a reasonable option (just be sure to store in a safe place away from little hands!)

We also tested *Metagenics Bone Builder Forte*, which provides 420 mg of calcium in a microcrystalline hydroxyapatite complex and 50 mcg (2,000 IU) of vitamin D — and we found a bit more of both. Although Approved, it is not our *Top Pick* because it's 4-times the cost of as *Bayer Citracal Petites* in terms of getting calcium and there is no reason to believe that calcium from **hydroxyapatite** is superior to that from calcium citrate.

Vitamin D, Calcium, and Magnesium: Both products tested in this category -- *Caltrate Minis* and *GNC Calcium Plus* -- were Approved for quality and are fairly inexpensive, although both use calcium carbonate and magnesium oxide, which are less bulky than other forms (keeping pill size down) but may not be absorbed as well as other forms such as citrate if taken on an empty stomach by people with low stomach acid, including those who take acid-blocking drugs.

Our *Top Pick* in this category is ***GNC Calcium Plus*** as it offers, per caplet (8 cents) a good dose of calcium (333 mg — we found 318 mg), magnesium (167 mg -- we found 172 mg) and 6.67 mcg (267 IU) of vitamin D3 (we found 8.6 mcg). The label suggests taking 3 caplets per day, and we would suggest taking just one caplet with a meal, and, if needed, a second with a later meal, so as not to get too much calcium at one time. We would not recommend taking the full 3-caplet dose per day, as that would provide 517 mg of magnesium per day, which could have a laxative effect.

Caltrate Minis is not our *Top Pick* in this category as it offers little magnesium — just 50 mg (we found 59.5 mg) per 2-tablet serving. While this permits the tablets to be smaller in size, the product is more like a calcium-vitamin D supplement. Each mini tablet offers 300 mg of calcium (we found a bit less — 281 mg) and 20 mcg (800 IU) of vitamin D (we found a bit more 23.6 mcg).

Vitamin D, Calcium, Magnesium, and Vitamin K: It's not clear that supplementing with vitamin K improves bone health, and most people already get sufficient vitamin K from their diets, as discussed in our Vitamin K Review. However, if you want a product combining calcium with vitamin K, vitamin D, and magnesium, our *Top Pick* is ***New Chapter Bone Strength Take Care*** — just be aware that it provides little magnesium. A single vegetarian slim tablet (35 cents), offers 302 mg of calcium, 8.3 mcg (333 IU) of vitamin D3, two forms of vitamin K: vitamin K1 (11.6 mcg) and vitamin K2 (15 mcg), and a small amount of magnesium — just 20.7 mg. We found a bit more than these listed amounts. It also claims to provide small amounts of strontium (1.8 mg) and vanadium (14 mcg), which are not essential

minerals. The calcium and magnesium in *New Chapter* are from algae, but there is no compelling research showing superiority of algae-based forms of these minerals. The label suggests taking three tablets daily with food, but we suggest not taking more than one tablet per serving to avoid getting too much calcium at one time.

Vitamin D, Calcium, Magnesium, Vitamin K, and Boron: We tested two products in this category, although neither is a *Top Pick* because one, *Life Extension Bone Restore with Vitamin K2*, was found to provide somewhat less vitamin K than listed and was, therefore, *Not* Approved, while the other, *AlgaeCal Plus*, is unusually expensive ($1.22 per 2-capsule serving) and we do not consider it a good value. (As noted earlier, in 2022 we tested *Jarrow Formulas BoneUp* — a popular product in this category — but found that it contained only 30.7% of its claimed vitamin K2 (as MK-7), despite containing its amounts of calcium, magnesium, boron, and vitamin D.)

With that said, if you don't mind paying the high price, a 2-veggie capsule serving of *AlgaeCal Plus* does deliver good amounts of all five of the nutrients in this category (as well as some vitamin C). The calcium and some of the magnesium are derived from algae, but there is no proven clinical advantage with this source, and it doesn't justify the premium price. It would be far less expensive to get these ingredients by combining other, less expensive, supplements that ConsumerLab has Approved. The label on *AlgaeCal Plus* suggests taking a two-capsule serving with a meal twice daily (4 capsules in total), but, be aware that this would provide a total of 458.6 mg of magnesium (based on the amounts we found, which is about 100 mg more than listed) and this exceeds the daily tolerable upper intake level (UL) for magnesium of 350 mg, above which there is increasing risk of a laxative effect.

Although *Life Extension Bone Restore with Vitamin K2* was *Not* Approved because it fell somewhat short on its vitamin K2 as trans MK-7 (we found 80.8% of its listed 200 mcg), this is still a substantial dose of vitamin K and the product did contain it its listed amounts (or somewhat more) of calcium, magnesium, and boron. The label suggests taking 4 capsules daily — although it would seem best to not take more than two at a time to reduce competition for mineral absorption, particularly as the major forms in the product are calcium carbonate and magnesium oxide, which might not be the best absorbed forms for people with low stomach acid.

Test Results by Product:

Listed below are the test results for 29 supplements containing vitamin D. Products are grouped by formulation: softgels and capsules, gummies, and liquids, followed by vitamin D combinations formulas that include calcium, magnesium, vitamin K, and/or boron. Within each group, products are listed alphabetically. ConsumerLab.com selected 18 of these products. Eleven other products (each indicated with a CL flask) were tested at the request of their manufacturers/distributors through CL's voluntary Quality Certification Program and are included for having passed testing.

Shown for each product is the claimed amount and form of the tested ingredient(s), serving size recommended on its label, results of testing, pill size, taste (if a gummy, chewable, or liquid), price cost per 1,000 IU of vitamin D, and notable features. Products listed as "Approved" met their label claims and ConsumerLab.com's quality criteria (see Passing Score). The full list of ingredients is available for each product in the last column.

Results of ConsumerLab.com Testing of Vitamin D Supplements
(Including Combinations With Calcium, Magnesium, Vitamin K, and Boron)

(Price Checks are not included in printed reviews)

Approval Status **Product Name**	**Claimed Amount and Form of Key Ingredient(s) Per Serving** **Heavy Metals**	**Suggested Serving on Label** **Pill Size**	**Cost Per Suggested Serving** **[Per 25 mcg Vitamin D *Found*]**	**Notable Features and Precautions on Label**	**Full List of Ingredients Per Serving**
Vitamin D Only: Softgels and Capsules					
APPROVED Top Pick for vegan high dose Doctor's Best® Vegan D3 2,500 IU  Dist. by Doctor's Best, Inc.	1 veggie cap **D3: 62.5 mcg (2,500 IU) [Found 83.4 mcg (3,336 IU) ✓]** **Heavy Metals:**	Take 1 capsule daily with food, or as recommended by a nutritionally informed physician. Medium/large veggie cap	$0.17/veggie cap **[$0.05]** $10.10/60 veggie caps	*Non-GMO / Gluten Free / Soy Free / Vegan.*	1 veggie cap Vitamin D3 (as cholecalciferol) (Vitamin D3) 62.5 mcg (2,500 IU). Other Ingredients: Microcrystalline cellulose, hypromellose (vegetarian capsule) Additional Information 1 veggie cap Vitamin D3 (as cholecalciferol) (Vitamin D3) 62.5 mcg (2,500 IU). Other Ingredients: Microcrystalline cellulose, hypromellose (vegetarian capsule), maltodextrin, starch, sucrose, silicon dioxide, d-alpha tocopherol, ascorbyl palmitate.

APPROVED Top Pick for vegan very high dose Garden of Life® Vitamin Code® Raw D3™ 5,000 IU (125 mcg)  Dist. by Garden of Life LLC	1 vegetarian capsule **D3: 125 mcg (5,000 IU) [Found 169.7 mcg (6,789.1 IU) ✓]** **Heavy Metals:** Pass Lead: 0.05 mcg Arsenic: 0.07 mcg Cadmium: 0.02 mcg Mercury: 0.003 mcg	Adults take 1 capsule daily or directed by your healthcare practitioner. Best when taken with a meal. Capsule may be opened and contents may be added to water or juice. Large vegetarian capsule	$0.45/vegetarian capsule **[$0.07]** $26.94/60 vegetarian capsules	High omega-9 cracked-wall chlorella 250 mg, raw organic fruit & vegetable blend 150 mg & raw probiotic & enzyme blend 60 mg per vegetarian capsule. *Non GMO Project Verified seal. NSF® Certified Gluten-Free seal. Kosher.*	1 vegetarian capsule Vitamin D (as D3 from culture of Saccharomyces cerevisiae) 125 mcg (5,000 IU), High Omega-9 Cracked-Wall Chlorella 250 mg, Raw Organic Fruit & Vegetable Blend [Organic Apple (fruit), Organic Beet (root), Organic Broccoli (stalk & flower) Additional Information 1 vegetarian capsule Vitamin D (as D3 from culture of Saccharomyces cerevisiae) 125 mcg (5,000 IU), High Omega-9 Cracked-Wall Chlorella 250 mg, Raw Organic Fruit & Vegetable Blend [Organic Apple (fruit), Organic Beet (root), Organic Broccoli (stalk & flower), Organic Carrot (root), Organic Spinach (leaf), Organic Tomato (fruit), Organic Strawberry (fruit), Organic Tart Cherry (fruit), Organic Green Bell Pepper (fruit), Organic Blackberry (fruit), Organic Brussels Sprout (leaf), Organic Ginger (root), Organic Garlic (bulb), Organic Green Onion (bulb), Organic Blueberry (fruit), Organic Parsley (leaf), Organic Cauliflower (flower & stem), Organic Raspberry (fruit), Organic Red Cabbage (leaf), Organic Kale (leaf), Organic Cucumber gourd), Organic Celery (stalk), Organic Asparagus (flower & stem)] 150 mg, Raw Probiotic & Enzyme Blend [Lipase, Protease, Aspergillopepsin, beta-Glucanase, Celllulase, Bromelain, Phytase, Lactase, Papain, Peptidase, Pectinase, Hemicellulase, Xylanase, [*Lactobacillus bulgaricus, Lactobacillus plantarum*] (500 Million CFU)] 60 mg. Other Ingredients: Vegetable cellulose (capsule), organic rice (hull).

APPROVED Top Pick for high dose pill Kirkland Signature [Costco] D3 50 mcg  Dist. by Costco Wholesale Corporation	1 softgel **D3: 50 mcg (2,000 IU) [Found 56.9 mcg (2,277.6 IU) ✓]** **Heavy Metals:**	Take one (1) softgel daily, preferably with a meal. Medium softgel	$0.02/softgel **[$0.01]** $12.49/600 softgels	*USP® Dietary Supplement Verified seal. No Artificial Colors. No Artificial Flavors. No Yeast, Starch or Gluten.*	1 softgel Vitamin D3 50 mcg (2,000 IU). Ingredients: Soybean Oil, Gelatin (Porcine), Glycerin, Water, Vitamin D3 (Cholecalciferol).
APPROVED Top Pick for moderate dose pill Nature Made® D3 1,000 IU (25 mcg)  Dist. by Nature Made Nutritional Products	1 softgel **D3: 25 mcg (1,000 IU) [Found 27.5 mcg (1,098 IU) ✓]** **Heavy Metals:**	Adults, take 1 softgel daily with water and a meal. Medium softgel	$0.04/softgel **[$0.04]** $12.20/300 softgels	*USP® Dietary Supplement Verified seal. No Color Added. No Artificial Flavors. Gluten Free.*	1 softgel Vitamin D3 (as Cholecalciferol) 25 mcg (1,000 IU). Other Ingredients: Soybean Oil, Gelatin, Glycerin.

APPROVED NOW® High Potency Vitamin D-3 2,000 IU  Dist. by NOW FOODS	1 softgel **D3: 50 mcg (2,000 IU) [Found 53.1 mcg (2,123.5 IU) ✓]** **Heavy Metals:**	Take 1 softgel daily with a meal. Medium softgel	$0.08/softgel **[$0.04]** $2.43/30 softgels	*Non-GMO. Kosher. Halal.* **Precaution:** Not manufactured with yeast, wheat, gluten, soy, corn, milk, egg, fish, shellfish or sesame ingredients Additional Information *Non-GMO. Kosher. Halal.* **Precaution:** Not manufactured with yeast, wheat, gluten, soy, corn, milk, egg, fish, shellfish or sesame ingredients. Produced in a GMP facility that processes other ingredients containing these allergens.	1 softgel Vitamin D (as D3 Cholecalciferol) (from Lanolin) 50 mcg (2,000 IU). Other Ingredients: Extra Virgin Olive Oil, Softgel Capsule (bovine gelatin (BSE-free) Additional Information 1 softgel Vitamin D (as D3 Cholecalciferol) (from Lanolin) 50 mcg (2,000 IU). Other Ingredients: Extra Virgin Olive Oil, Softgel Capsule (bovine gelatin (BSE-free), glycerin, water) and Safflower Oil.

APPROVED Top Pick for very high dose pill Vitacost® Vitamin D3 125 mcg (5,000 IU)  Dist. by Vitacost.com, Inc.	1 softgel **D3: 125 mcg (5,000 IU) [Found 146.1 mcg (5,844 IU) ✓]** **Heavy Metals:**	As A Dietary Supplement For Adults 18 Years Of Age And Over, Take 1 Softgel Daily Or As Directed By A Healthcare Professional. Medium softgel	$0.03/softgel **[$0.01]** $5.99/200 softgels	*Free of: Milk, Eggs, Peanuts, Tree Nuts, Crustacean Shellfish, Fish, Soy, Gluten, Titanium Dioxide.*	1 softgel Vitamin D (as cholecalciferol [D3]) 125 mcg (5,000 IU). Other Ingredients: Safflower Oil, Gelatin, Vegetable Glycerin And Water.
APPROVED Top Pick for vegan moderate dose Whole Earth & Sea® Vegan Bioenhanced Vitamin D3 1,000 IU  Dist. by Natural Factors	1 vegetarian capsule **D3: 25 mcg (1,000 IU) [Found 24 mcg (961.6 IU) ✓]** **Heavy Metals:**	1 capsule daily or as directed by a health care practitioner. Large vegetarian capsule	$0.19/vegetarian capsule **[$0.20]** $16.97/90 vegetarian capsules	*on-GMO. Contains no artificial colours, preservatives, or sweeteners; no dairy, starch, sugar, wheat, gluten, yeast, soy, egg, fish, shellfish, animal products, salt, tree nuts, or GMOs. Suitable for vegetarians/ vegans.*	1 vegetarian capsule Vitamin D3 (cholecalciferol) (lichen) 1,000 IU (25 mcg). Non-medical ingredients: Microcrystalline cellulose, vegetarian capsule Additional Information 1 vegetarian capsule Vitamin D3 (cholecalciferol) (lichen) 1,000 IU (25 mcg). Non-medical ingredients: Microcrystalline cellulose, vegetarian capsule (carbohydrate gum [cellulose], purified water), vegetable lubricant (palm).
Vitamin D Only: Gummy					

APPROVED Top Pick for gummy Nordic Naturals® Vitamin D3 Gummies - Great Wild Berry Taste  Mfd. by Nordic Naturals, Mfg.	1 gummy **D3: 25 mcg (1,000 IU) [Found 26 mcg (1,040.8 IU) ✓]** **Heavy Metals:**	One gummy daily, with food, or as directed by your health care professional. Medium/large gumdrop shaped gummy *Taste: Soft, sugar-coated gummy with sweet, slightly sour, berry flavor (2 grams of sugar per gummy* *Additional Information* *One gummy daily, with food, or as directed by your health care professional.* *Medium/large gumdrop shaped gummy* *Taste: Soft, sugar-coated gummy with sweet, slightly sour, berry flavor (2 grams of sugar per gummy; 10 Calories).*	$0.16/gummy **[$0.15]** $18.66/120 gummies	Iron 1.4 mg & sodium 5 mg per gummy *igen™ Non-GMO Tested seal. No gluten, milk derivatives, or artificial colors or flavors.*	1 gummy Calories 10, Total Carbohydrate 2 g, Total Sugars [Includes 2 g Added Sugars] 2 g, Vitamin D3 (Cholecalciferol) 25 mcg (1,000 IU), Iron 1.4 mg, Sodium 5 mg. Other Ingredients: Organic tapioca syrup Additional Information 1 gummy Calories 10, Total Carbohydrate 2 g, Total Sugars [Includes 2 g Added Sugars] 2 g, Vitamin D3 (Cholecalciferol) 25 mcg (1,000 IU), Iron 1.4 mg, Sodium 5 mg. Other Ingredients: Organic tapioca syrup, organic cane sugar, purified water pectin, citric acid, fumaric acid, natural flavor, sodium citrate dihydrate, fruit and vegetable juice (color).
Vitamin D Only: Liquids					

NOT APPROVED Biotics Research® Bio-D-Mulsion Forte®  Dist. by Biotics Research Corp.	2 drops [0.08 mL] **D3: 100 mcg (4,000 IU) [Found 195 mcg (7,798.4 IU) (195% of listed amount)]** **Heavy Metals:**	Two (2) drops each day as a dietary supplement or as otherwise directed by a healthcare professional. *Taste: Somewhat thick, white, oily liquid, although thicker liquid and squeeze bottle* *Additional Information* *Two (2) drops each day as a dietary supplement or as otherwise directed by a healthcare professional.* *Taste: Somewhat thick, white, oily liquid, although thicker liquid and squeeze bottle with dropper top make it easy to control number of drops, which is important because a single drop is listed as 50 mcg (2,000 IU) and we found 95% more than listed.*	$0.08/2 drops **[$0.01]** $28.13/1 fl oz [30 mL] bottle (approx. 375 servings)	*This product is gluten and dairy free.*	2 drops Vitamin D (as cholecalciferol) 100 mcg (4,000 IU). Other Ingredients: Water, gum arabic and sesame seed oil.

APPROVED Carlson® Plant-Based Super Daily® D3  Dist. by Carlson Division of J.R. Carlson Laboratories, Inc.	1 drop [0.028 mL] **D3: 50 mcg (2,000 IU) [Found 54.6 mcg (2,184 IU) ✓]** **Heavy Metals:**	Adults: take one drop daily or as directed by your healthcare professional. May be put in food or a drink. *Taste: Oily drop with no taste. Caution: A single drop from the dropper-top is about 50 mcg (2,000 IU), so avoid excess drops* *Additional Information* *Adults: take one drop daily or as directed by your healthcare professional. May be put in food or a drink.* *Taste: Oily drop with no taste. Caution: A single drop from the dropper-top is about 50 mcg (2,000 IU), so avoid excess drops - although drops come out slowly. Cap is not child-resistant.*	$0.23/drop **[$0.11]** $21.00/0.086 fl oz [2.54 mL] bottle (approx. 91 servings)	*Gluten-free. Vegetarian. No Artificial Preservatives. Certified Sourcing.*	1 drop Vitamin D (as cholecalciferol) 50 mcg (2,000 IU). Other Ingredients: Medium chain triglyceride oil (from Coconut), d-alpha tocopherol.

APPROVED Carlson® Super Daily® D3 2,000 IU  Dist. by Carlson Division of J.R. Carlson Laboratories, Inc.	1 drop [0.028 mL] **D3: 50 mcg (2,000 IU) [Found 57.8 mcg (2,313.8 IU) ✓]** **Heavy Metals:**	Adults: take one drop daily or as directed by your healthcare professional. May be put in food or a drink. *Taste: Oily drop with no taste. Caution: A single drop from the dropper-top is about 50 mcg (2,000 IU), so avoid excess drops* *Additional Information* *Adults: take one drop daily or as directed by your healthcare professional. May be put in food or a drink.* *Taste: Oily drop with no taste. Caution: A single drop from the dropper-top is about 50 mcg (2,000 IU), so avoid excess drops - although drops come out slowly. Cap is not child-resistant.*	$0.05/drop **[$0.02]** $17.85/0.35 fl oz [10.3 mL] bottle (approx. 368 servings)	*Gluten-free. Soy-free. No Artificial Preservatives.*	1 drop Vitamin D (as cholecalciferol) 50 mcg (2,000 IU). Other Ingredients: Medium chain triglyceride oil (from coconut).

APPROVED Pure Encapsulations® Vitamin D3 Liquid  Dist. by Pure Encapsulation	1 drop [0.03 mL] **D3: 25 mcg (1,000 IU) [Found 29.3 mcg (1,171.2 IU) ✓]** **Heavy Metals:**	Children ages 3-8, take 1-2 drops daily. Adults and children ages 9 and up, take 1-4 drops daily, or as directed by a health professional. Consume with food. *Taste: Oily drop with no taste* *Additional Information* *Children ages 3-8, take 1-2 drops daily. Adults and children ages 9 and up, take 1-4 drops daily, or as directed by a health professional. Consume with food.* *Taste: Oily drop with no taste. A single drop from the dropper top is about 25 mcg (1,000 IU), so avoid excess drops, which can come out fast. Childproof, push and twist top.*	$0.04/drop **[$0.04]** $31.60/0.75 fl oz [22.5 mL] bottle (approx. 750 servings)	*GFCO.org Certified Gluten Free seal.*	1 drop Vitamin D (as cholecalciferol) (D3) 25 mcg (1,000 IU). Other Ingredients: Medium chain triglycerides.

APPROVED Top Pick overall and among liquids Source Naturals® Vitamin D-3  Dist. by Source Naturals, Inc.	9 drops [0.17 mL] **D3: 50 mcg (2,000 IU) [Found 57.3 mcg (2,292 IU) ✓]** **Heavy Metals:**	9 drops once daily in a drink. *Taste: Oily drops with mild orange flavor. Easier to control drops than Nordic and Carlson due to traditional bulb-dropper and smaller dose per single drop (about 5.6 mcg or 222 IU per drop).*	$0.03/9 drops **[$0.01]** $17.55/4 fl oz [118.3 mL] bottle (approx. 695 servings)	*Contains no yeast, dairy, egg, gluten, corn, soy or wheat.* *Contains no sugar, starch, salt, preservatives, or artificial color, flavor or fragrance.*	9 drops Vitamin D-3 (as cholecalciferol) 50 mcg (2,000 IU). Other Ingredients: Medium chain tri-glycerides, orange and lemon essential oils.
Vitamin D & Calcium:					

APPROVED Top Pick for vitamin D and calcium combination product Bayer Citracal® Petites  Dist. by Bayer HealthCare LLC	2 coated caplets **D3: 12.5 mcg (500 IU) [Found 17.7 mcg (707 IU) ✓]** Calcium: 400 mg (calcium citrate) [Found 375.1 mg ✓] **Heavy Metals:** Pass Lead: 0.45 mcg Arsenic: 0.18 mcg Cadmium: 0.07 mcg Mercury: 0.005 mcg Also passed disinte-gration testing	Adults and children 12 year of age and older. Take 1 serving (2 caplets) twice daily with or without food or as recommended by your health professional. Take with a full glass of water in an upright position. Large coated caplet	$0.14/2 coated caplets **[$0.19]** $13.50/200 coated caplets	Sodium 5 mg per 2 coated caplets	2 coated caplets Total Sugars [Includes 0 g Added Sugars] 0 g, Sugar Alcohol 0 g, Vitamin D 12.5 mcg (500 IU), Calcium 400 mg, Sodium 5 mg. Ingredients: Calcium Citrate, Polyethylene Glycol, Croscarmellose Sodium; Less than 2% of: Hydroxypropyl Methylcellulose, Magnesium Stearate Additional Information 2 coated caplets Total Sugars [Includes 0 g Added Sugars] 0 g, Sugar Alcohol 0 g, Vitamin D 12.5 mcg (500 IU), Calcium 400 mg, Sodium 5 mg. Ingredients: Calcium Citrate, Polyethylene Glycol, Croscarmellose Sodium; Less than 2% of: Hydroxypropyl Methylcellulose, Magnesium Stearate, Oligofructose Enriched Inulin, Propylene Glycol Dicaprylate/ Dicaprate, Talc, Titanium Dioxide (color), Vitamin D3 (Cholecalciferol).

APPROVED Top Pick for vitamin D and calcium combination gummy product Kirkland Signature [Costco] Adult Gummies Calcium 500 mg with D3 & Zinc - Orange & Cherry Natural Fruit Flavors  Dist. by Costco Wholesale Corporation	2 gummies **D3: 25 mcg (1,000 IU) [Found 27.2 mcg (1,088.8 IU) ✓]** Calcium: 500 mg (tribasic calcium phosphate) [Found 523.6 mg ✓] **Heavy Metals:** Pass Lead: 0.19 mcg Arsenic: 0.52 mcg Cadmium: Mercury:	Chew two (2) gummies daily, preferably with a meal. Large gummy *Taste: Large, soft, sugar-coated gummy with sweet, fruit flavor (5 g added sugar per 2 gummies; 25 Calories)*	$0.33/2 gummies **[$0.31]** $19.99/120 gummies	Phosphorus 230 mg & zinc 7 mg per 2 gummies *USP® Dietary Supplement Verified seal. No Artificial Flavors. No Yeast or Gluten. No Lactose.* **Precaution:** Contains bioengineered food ingredients.	2 gummies Calories 25, Total Carbohydrate 6 g, Total Sugars [Includes 5 g Added Sugars] 5 g, Vitamin D 25 mcg (1,000 IU), Calcium 500 mg, Phosphorus 230 mg, Zinc 7 mg. Ingredients: Glucose Syrup, Cane Sugar, Water, Tribasic Calcium Phosphate Additional Information 2 gummies Calories 25, Total Carbohydrate 6 g, Total Sugars [Includes 5 g Added Sugars] 5 g, Vitamin D 25 mcg (1,000 IU), Calcium 500 mg, Phosphorus 230 mg, Zinc 7 mg. Ingredients: Glucose Syrup, Cane Sugar, Water, Tribasic Calcium Phosphate, Modified Food Starch, Gelatin (Porcine), Citric Acid, Natural Flavors, Vegetable and Fruit Juice (Color), Maltodextrin, Lactic Acid, Zinc Citrate, Cholecalciferol.

APPROVED Metagenics® Bone Builder® Forte  Mfd. by Metagenics	2 capsules **D3: 50 mcg (2,000 IU) [Found 62.4 mcg (2,496 IU) ✓]** Calcium: 420 mg (microcry-lstalline hydroxy-apatite complex) [Found 478.4 mg ✓] **Heavy Metals:** Pass Lead: 0.67 mcg Arsenic: 0.1 mcg Cadmium: Mercury:	Take two capsules once daily or as directed by your healthcare practitioner. Large capsule	$0.77/2 capsules **[$0.31]** $69.58/180 capsules	Phosphorus 160 mg & microcrystalline hydroxyapatite concentrate 1.9 g per 2 capsules *GFCO.org Certified Gluten Free seal. This product is non-GMO and gluten-free.*	2 capsulesVitamin D (as cholecalciferol) 50 mcg (2,000 IU), Calcium (as MCHC) 420 mg, Phosphorus (as MCHC) 160 mg, Microcrystalline Hydroxyapatite Concentrate (MCHC) 1.9 g. Other Ingredients: Capsule Additional Information 2 capsulesVitamin D (as cholecalciferol) 50 mcg (2,000 IU), Calcium (as MCHC) 420 mg, Phosphorus (as MCHC) 160 mg, Microcrystalline Hydroxyapatite Concentrate (MCHC) 1.9 g. Other Ingredients: Capsule (hydroxypropylmethylcellulose), microcrystalline cellulose, stearic acid (vegetable), and magnesium stearate (vegetable).
Vitamin D & Vitamin K:					

APPROVED Top Pick for vitamin D with vitamin K2 as MK-7 Carlson® Super Daily® D3 + K2  Dist. by Carlson Div. of J.R. Carlson Laboratories, Inc.	2 drops [0.056 mL] **D3: 50 mcg (2,000 IU) [Found 60.5 mcg (2,418.7 IU) ✓]** K2 as MK-7: 45 mcg [Found 41.6 mcg ✓] **Heavy Metals:**	Adults: take two drops daily or as directed by your healthcare professional. May be put in food or a drink. *Taste: A light oil with no taste.*	$0.14/2 drops **[$0.06]** $25.42/0.34 fl oz [10.16 mL] bottle (approx. 181 servings)	*Gluten-free. Soy-free. No Artificial Preservatives.*	2 drops Vitamin D (as cholecalciferol) 50 mcg (2,000 IU), Vitamin K2 [as MK-7 (menaquinone-7)] 45 mcg. Other Ingredients: Medium chain triglyceride oil (coconut and palm source), antioxidant blend (d-alpha tocopherol, rosemary extract).
APPROVED Innovixlabs Vitamin D3 + K2  Dist. by InnovixLabs -A Division of Innovix Pharma Inc.	1 softgel **D3: 125 mcg (5,000 IU) [Found 179 mcg (7,161.8 IU) ✓]** K2 as MK-4: 500 mcg [Found 638 mcg ✓] K2 as MK-7: 100 mcg [Found 155 mcg ✓] **Heavy Metals:**	Take one softgel daily with a meal. Do not take more than one softgel per day unless recommended by a doctor. Medium/large softgel	$0.50/softgel **[$0.07]** $29.99/60 softgels	Vitamin A 900 mcg (3,000 IU) per softgel *Does Not Contain: Dairy, eggs, corn, shellfish, peanuts, wheat/gluten, soy protein, sugar, GMO, yeast, artificial colors or flavors.* Source: Encapsulated, packaged, and third-party tested in USA with domestic and international ingredients.	1 softgel Vitamin A (from Cod Liver Oil and Vitamin A Palmitate) 900 mcg (3,000 IU), Vitamin D3 (as Cholecalciferol) 125 mcg (5,000 IU), Vitamin K2 MK-4 (as Menatetrenone) 500 mcg, Vitamin K2 MK-7 (as Menaquinone-7) 100 mcg. Other Ingredients: Medium Chain Triglyceride Oil Additional Information 1 softgel Vitamin A (from Cod Liver Oil and Vitamin A Palmitate) 900 mcg (3,000 IU), Vitamin D3 (as Cholecalciferol) 125 mcg (5,000 IU), Vitamin K2 MK-4 (as Menatetrenone) 500 mcg, Vitamin K2 MK-7 (as Menaquinone-7) 100 mcg. Other Ingredients: Medium Chain Triglyceride Oil, Extra Virgin Olive Oil, Gelatin, Glycerin, Purified Water, Carob Color.

APPROVED Life Extension® Vitamins D and K with Sea-Iodine™  Dist. by Quality Supplements and Vitamins, Inc.	1 capsule **D3: 125 mcg (5,000 IU) [Found 160.5 mcg (6,421.8 IU) ✓]** K1: 1,000 mcg [Found 1,475 mcg ✓] K2 as MK-4: 1,000 mcg [Found 1,378 mcg ✓] K2 as *trans* MK-7: 100 mcg [Found 115 mcg ✓] **Heavy Metals:**	Take one (1) capsule once daily with food, or as recommended by a healthcare practitioner. Medium/large capsule	$0.30/capsule **[$0.05]** $18.00/60 capsules	Iodine 1,000 mcg per capsule *Gluten Free. Non GMO.*	1 capsule Vitamin D3 (as cholecalciferol) 125 mcg, Vitamin K activity from: [Vitamin K1 (as phytonadione) 1,000 mcg, Vitamin K2 (as menaquinone-4) 1,000 mcg, Vitamin K2 (as trans menaquinone-7) 100 mcg] 2,100 mcg, Iodine [from Sea-Iodine™ Complex Blend (organic kelp and bladderwrack extracts, potassium iodide)] 1,000 mcg. Other Ingredients: Microcrystalline cellulose Additional Information 1 capsule Vitamin D3 (as cholecalciferol) 125 mcg, Vitamin K activity from: [Vitamin K1 (as phytonadione) 1,000 mcg, Vitamin K2 (as menaquinone-4) 1,000 mcg, Vitamin K2 (as trans menaquinone-7) 100 mcg] 2,100 mcg, Iodine [from Sea-Iodine™ Complex Blend (organic kelp and bladderwrack extracts, potassium iodide)] 1,000 mcg. Other Ingredients: Microcrystalline cellulose, vegetable cellulose (capsule), maltodextrin. Food starch-modified, dicalcium phosphate, stearic acid, silica.

NOT APPROVED Sports Research® D3 + K2  Dist. by Sports Research	1 veggie softgel **D3: 125 mcg (5,000 IU) [Found 193 mcg (7,720 IU) (154.4% of listed amount)]** K2 as MK-7: 100 mcg [Found 112.9 mcg ✓] **Heavy Metals:**	Adults take 1 veggie softgel daily with food, or as recommended by a qualified healthcare professional. Medium/large veggie softgel	$0.40/veggie softgel **[$0.04]** $23.95/60 veggie softgel	*Non GMO Project Verified seal. Vegan.org Certified Vegan seal. Gluten-Free. Vegan.* **Precaution:** Contains: Tree Nuts (coconut).	1 veggie softgel Vitamin D (as D3, cholecalciferol) (from lichen) (Vegadelight) 125 mcg (5,000 IU), Vitamin K2 (as menaquinone-7) (MK-7 from chickpea) 100 mcg. Other Ingredients: Coconut MCT oil Additional Information 1 veggie softgel Vitamin D (as D3, cholecalciferol) (from lichen) (Vegadelight) 125 mcg (5,000 IU), Vitamin K2 (as menaquinone-7) (MK-7 from chickpea) 100 mcg. Other Ingredients: Coconut MCT oil, Plantgel™ capsule (non-GMO modified tapioca starch, vegetable glycerin, purified water, turmeric [for color]), olive oil.
APPROVED Top Pick for vitamin D with vitamin K2 as MK-4 Thorne Vitamin D + K2  Dist. by Thorne Research, Inc.	2 drops [0.05 mL] **D3: 25 mcg (1,000 IU) [Found 32.8 mcg (1,312.6 IU) ✓]** K2 as MK-4: 200 mcg [Found 198.6 mcg ✓] **Heavy Metals:**	Take 2 drops one to three times daily or as recommended by your health-care practitioner. Invert bottle to dispense individual drops. May be added to food or mixed in beverages. Do not refrigerate. *Taste: A light oil with no taste.*	$0.05/2 drops **[$0.04]** $29.00/1 fl oz [30 mL] bottle (approx. 600 servings)	None.	2 drops Vitamin D (as Vitamin D3) 25 mcg (1,000 IU), Vitamin K (as Vitamin K2 (Menatetrenone)) 200 mcg. Other Ingredients: Medium Chain Triglyceride Oil, Mixed Tocopherols.

APPROVED USANA® Vitamin D  Mfd. by USANA Health Sciences, Inc.	1 tablet **D3: 50 mcg (2,000 IU) [Found 53.7 mcg (2,148.8 IU) ✓]** K2 as MK-4 and MK-7: 30 mcg [Found 29.6 mcg ✓ (13.1 mcg MK-4 and 16.4 mcg MK-7)] **Heavy Metals:** Also passed disinte-gration testing	Small circular tablet Take one (1) tablet daily, preferably with food.	$0.29/tablet **[$0.14]** $24.50/84 tablets	*Kosher.*	1 tablet Vitamin D3 (as Cholecalciferol) 50 mcg, Vitamin K (as Menaquinone MK4 & MK7) 30 mcg. Other Ingredients: Microcrystalline Cellulose, Pregelatinized Starch, Croscar-mellose Sodium, Ascorbyl Palmitate Additional Information 1 tablet Vitamin D3 (as Cholecalciferol) 50 mcg, Vitamin K (as Menaquinone MK4 & MK7) 30 mcg. Other Ingredients: Microcrystalline Cellulose, Pregelatinized Starch, Croscarmellose Sodium, Ascorbyl Palmitate, Silicon Dioxide, Organic Maltodextrin, Organic Sunflower Lecithin, Organic Palm Olein, Organic Gaur Gum.
Vitamin D, Calcium & Magnesium:					

APPROVED Caltrate Minis  Dist. by GSK Consumer Healthcare	2 mini tablets **D3: 40 mcg (1,600 IU) [Found 47.1 mcg (1,882.4 IU) ✓]** Calcium: 600 mg (calcium carbonate) [Found 561.9 mg ✓] Magnesium: 50 mg (magnesium oxide) [Found 59.5 mg ✓] **Heavy Metals:** Pass Lead: 0.23 mcg Arsenic: 0.26 mcg Cadmium: 1.4 mcg Mercury: Also passed disinte-gration testing	Adults: Take two (2) mini tablets once daily with food or as directed by your physician. Not formulated for use in children. Medium/large mini tablet	$0.24/2 mini tablets **[$0.13]** $17.99/150 mini tablets	Zinc 7.5 mg & manganese 1.8 mg per 2 mini tablets *Gluten Free.*	2 mini tablets Vitamin D3 40 mcg (1,600 IU), Calcium 600 mg, Magnesium 50 mg, Zinc 7.5 mg, Manganese 1.8 mg. Ingredients: Calcium Carbonate, Magnesium Oxide, Maltodextrin, Microcrystalline Cellulose. Contains <2% of: Blue 2 Lake, Cholecalciferol (Vit. D3), Copper Sulfate, Croscarmellose Sodium, Magnesium Stearate, Manganese Sulfate Additional Information 2 mini tablets Vitamin D3 40 mcg (1,600 IU), Calcium 600 mg, Magnesium 50 mg, Zinc 7.5 mg, Manganese 1.8 mg. Ingredients: Calcium Carbonate, Magnesium Oxide, Maltodextrin, Microcrystalline Cellulose. Contains <2% of: Blue 2 Lake, Cholecalciferol (Vit. D3), Copper Sulfate, Croscarmellose Sodium, Magnesium Stearate, Manganese Sulfate, Polyethylene Glycol, Polyvinyl Alcohol, Red 40 Lake, Sodium Ascorbate (to preserve freshness), Talc, Titanium Dioxide, Tocopherols (to preserve freshness), Yellow 6 Lake, Zinc Oxide.

APPROVED Top Pick for vitamin D, calcium and magnesium combination product GNC Calcium Plus®  Dist. by GNC Holdings, LLC	3 caplets **D3: 20 mcg (800 IU) [Found 25.8 mcg (1,033.4 IU) ✓]** Calcium: 1,000 mg (calcium carbonate) [Found 955.3 mg ✓] Magnesium: 500 mg (magnesium oxide) [Found 517.3 mg ✓] **Heavy Metals:** Pass Lead: 0.86 mcg Arsenic: 1.9 mcg Cadmium: 0.96 mcg Mercury: 0.004 mcg Also passed disinte-gration testing	Take three caplets daily. Large caplet	$0.25/3 caplets **[$0.24]** $14.99/180 caplets	*Gluten Free. No Artificial Flavor, Gluten Free, No Milk.*	3 caplets Vitamin D (as Cholecalciferol D-3) 20 mcg (800 IU), Calcium (as Calcium Carbonate) 1,000 mg, Magnesium (as Magnesium Oxide) 500 mg. Other Ingredients: Microcrystalline Cellulose, Hydroxypropyl Methylcellulose, Magnesium Stearate Vegetable Source, Titanium Dioxide (Mineral Whitener), Hydroxypropyl-cellulose, Sodium Starch Glycolate, Croscarmellose Sodium, Silicon Dioxide, Vegetable Acetoglycerides Additional Information 3 caplets Vitamin D (as Cholecalciferol D-3) 20 mcg (800 IU), Calcium (as Calcium Carbonate) 1,000 mg, Magnesium (as Magnesium Oxide) 500 mg. Other Ingredients: Microcrystalline Cellulose, Hydroxypropyl Methylcellulose, Magnesium Stearate Vegetable Source, Titanium Dioxide (Mineral Whitener), Hydroxypropyl-cellulose, Sodium Starch Glycolate, Croscarmellose Sodium, Silicon Dioxide, Vegetable Acetoglycerides, Polyethylene Glycol, Polysorbate 80.
Vitamin D, Calcium & Vitamin K:					

APPROVED NuBest® Tall 10+  Dist. by NuBest, Inc.	1 capsule **D3: 10 mcg (400 IU) [Found 13.5 mcg (540 IU) ✓]** Calcium: 220 mg (calcium carbonate) [Found 275.6 mg ✓] K2 as MK-7: 60 mcg [Found 51.6 mcg ✓] **Heavy Metals:** Pass Lead: 0.11 mcg Cadmium: 0.21 mcg Arsenic: 0.16 mcg Mercury:	Large capsule Should be used daily as a dietary supplement for children (10+) and teenagers. Take one (1) capsule twice daily after meals.	$0.92/capsule **[$1.70]** $55.00/60 capsules	NuBest® proprietary blend 140 mg & collagen hydrolysate 100 mg per capsule *Non GMO.*	1 capsule Vitamin D3 (as Cholecalciferol) 10 mcg, Calcium (as Calcium Carbonate) 220 mg, NuBest® Proprietary Blend [Poria Mycelium Powder, Eucommia Bark Extract, Motherwort Leaf Powder, Polygonatum Root Powder, Sichuan Lovage Rhizome Powder, *Ginkgo Biloba* Leaf Extract, 5-Hydroxytrytophan Additional Information 1 capsule Vitamin D3 (as Cholecalciferol) 10 mcg, Calcium (as Calcium Carbonate) 220 mg, NuBest® Proprietary Blend [Poria Mycelium Powder, Eucommia Bark Extract, Motherwort Leaf Powder, Polygonatum Root Powder, Sichuan Lovage Rhizome Powder, *Ginkgo Biloba* Leaf Extract, 5-Hydroxytrytophan (from *Griffonia simplicifolia* Seed Extract)] 140 mg, Collagen Hydrolysate (Bovine) 100 mg, Vitamin K2 (as Menaquinone-7) 60 mcg. Other Ingredients: Gelatin (Capsule).
Vitamin D, Calcium, Magnesium & Vitamin K:					

APPROVED Top Pick for vitamin D, calcium, magnesium and vitamin K combination product New Chapter® Plant Calcium Bone Strength Take Care®  Dist. by New Chapter, Inc.	3 vegetarian slim tablets **D3: 25 mcg (1,000 IU) [Found 35.3 mcg (1,412.4 IU) ✓]** Calcium: 905 mg (from organic algae *Litho-thamnion spp.*) [Found 958.3 mg ✓] Magnesium: 62 mg (from organic algae *Litho-thamnion spp.*) [Found 80.6 mg ✓] K1: 35 mcg [Found 52.9 mcg ✓] K2 as MK-7: 45 mcg [Found 59.4 mcg ✓] **Heavy Metals:** Pass Lead: 0.09 mcg Arsenic: 2.6 mcg Cadmium: 1.6 mcg Mercury:	Three Tablets Daily With Food. Large vegetarian slim tablet	$1.05/3 vegetarian slim tablets **[$0.74]** $41.97/120 vegetarian slim tablets	Strontium 5.5 mg & vanadium 14 mcg per 3 vegetarian slim tablets *USDA Organic seal. Non GMO Project Verified seal. NSF® Certified Gluten-Free seal. 100% vegetarian; no artificial flavors or colors.* **Precaution:** Contains: Fermented soy.	3 vegetarian slim tablets Vitamin D3 (as cholecalciferol from ferment media) 25 mcg (1,000 IU), Vitamin K1 (as phylloquinone from ferment media) 35 mcg, Vitamin K2 (as menaquinone-7) 45 mcg, Calcium (from organic algae *Lithothamnion spp.*) 905 mg, Magnesium (from organic algae *Lithothamnion spp.*) 62 mg, Strontium (from organic algae *Lithothamnion spp.*) 5.5 mg, Vanadium (from organic algae *Lithothamnion spp.*) 14 mcg. Other Ingredients: Organic gum acacia; Less than 2% of: ferment media (organic soy flour, organic *Saccharomyces cerevisiae*, organic alfalfa powder, papain [deactivated], bromelain [deactivated], lactic acid bacteria [*L. acidophilus, B. bifidum, L. rhamnosus*]), organic coating (organic maltodextrin, organic sunflower lecithin, organic palm oil, organic guar gum), organic MCT oil, organic psyllium husk, organic oat fiber, organic guar gum and organic agave fiber.

	Also passed disinte-gration testing				
Vitamin D, Calcium, Magnesium & Boron:					

APPROVED USANA® Magnecal D  Mfd. by USANA Health Sciences, Inc.	2 tablets **D3: 12.5 mcg (500 IU) [Found 16 mcg (639.5 IU) ✓]** Calcium: 260 mg (calcium citrate, calcium carbonate) [Found 269.2 mg ✓] Magnesium: 260 mg (magnesium citrate, magnesium carbonate) [Found 262.4 mg ✓] Boron: 0.66 mcg (boron cirtate) [Found 0.83 mcg ✓] **Heavy Metals:** Pass Lead: 0.14 mcg Arsenic: 0.11 mcg Cadmium: 0.3 mcg Mercury: 0.005 Also passed disinte-	Large tablet Adults take two (2) tablets twice daily, preferably with food.	$0.47/2 tablets **[$0.74]** $26.50/112 tablets	*Kosher.*	2 tablets Vitamin D3 (as Cholecalciferol) 12.5 mcg, Calcium (as Calcium Citrate and Calcium Carbonate) 260 mg, Magnesium (as Magnesium Citrate and Magnesium Carbonate) 260 mg, Boron (as Boron Citrate) 0.66 mg. Other Ingredients: Microcrystalline Cellulose, Ascorbyl Palmitate, Organic Maltodextrin, Calcium Silicate, Croscar-mellose Sodium, Organic Sunflower Lecithin, Organic Palm Olein, Organic Guar Gum.

	gration testing				
Vitamin D, Calcium, Magnesium, Vitamin K & Boron:					

APPROVED AlgaeCal Plus  Dist. by AlgaeCal Inc.	2 veggie capsules **D3: 20 mcg (800 IU) [Found 26 mcg (1,039.4 IU) ✓]** Calcium: 360 mg (AlgaeCal® *I. super-positum*) [Found 403.2 mg ✓] Magnesium: 175 mg (magnesium oxide, AlgaeCal® *I. super-positum*) [Found 229.3 mg ✓] K2 as MK-7: 50 mcg [Found 50.7 mcg ✓] Boron: 1.5 mg (boron glycinate) [Found 1.5 mg ✓] **Heavy Metals:** Pass Lead: 0.58 mcg Arsenic: 2.5 mcg Cadmium:	As Take 2 caps twice daily with meals (4 caps per day) to support bone strength. Large veggie capsule	$1.22/2 veggie capsules **[$1.17]** $219.00/three bottles of 120 veggie capsules (360 veggie capsules total)	Vitamin C 25 mg per 2 veggie capsules Manufactured In USA	2 veggie capsules Vitamin C (as Calcium Ascorbate) 25 mg, Vitamin D (as Cholecalciferol) 20 mcg (800 IU), Calcium (as AlgaeCal® *I. superpositum*) 360 mg, Magnesium (as Magnesium Oxide & AlgaeCal® *I. superpositum*) 175 mg, Boron (as Boron Glycinate) 1.5 mg, Vitamin K (as K2 Vital® Delta MK-7) 50 mcg. Other Ingredients: Vegetable cellulose (Vegetarian capsule), magnesium stearate (vegetable grade), microcrystalline cellulose.

	0.01 mcg Mercury: 0.002 mcg				

NOT APPROVED Life Extension® Bone Restore Calcium Supplement with Vitamin K2  Dist. by Quality Supplements and Vitamins, Inc.	4 capsules **D3: 25 mcg (1,000 IU) [Found 31.4 mcg (1,257.4 IU) ✓]** Calcium: 700 mg (calcium carbonate, calcium citrate malate, calcium bisglycinate, calcium fructoborate) [Found 671.1 mg ✓] Magnesium: 300 mg (magnesium oxide) [Found 325.2 mg ✓] K2 as *trans* MK-7: 200 mcg [Found only 161.6 mcg (80.8% of listed amount)] Boron: 3 mg (calcium fructoborate) [Found 3.2 mcg ✓]	Take four (4) capsules daily, or as recommended by a healthcare practitioner. Scientific studies suggest calcium supplementation in divided doses with food in the morning and evening may yield the best results. Large capsule	$0.60/4 capsules **[$0.48]** $18.00/120 capsules	Zinc 2 mg, manganese 1 mg & silicon 5 mg per 4 capsules *Gluten Free.*	4 capsules Vitamin D3 [as cholecalciferol] 25 mcg (1,000 IU), Vitamin K [as *trans* menaquinone-7] 200 mcg, Calcium [as carbonate, citrate malate, bisglycinate, fructoborate] 700 mg, Magnesium [as magnesium oxide] 300 mg, Zinc [as zinc amino acid chelate] 2 mg, Manganese [as manganese amino acid chelate] 1 mg, Silicon [from horsetail extract (herb)] 5 mg, Boron [calcium fructoborate as patented Fruitex B® OsteoBoron®] 3 mg. Other Ingredients: Vegetable cellulose (capsule), stearic acid, ascorbyl palmitate, maltodextrin, microcrystalline cellulose, silica, food starch-modified.

	Heavy Metals: Pass Lead: 0.38 mcg Arsenic: 1.2 mcg Cadmium: 0.68 mcg Mercury:				

Products tested in 2024 and 2025

ConsumerTips™:

What to Consider When Buying:

Who Is Likely to Have Low Levels of Vitamin D?

Inadequate vitamin D intake is common in **people who live in northern climates** (north of a line from Boston to the northern border of California), especially if they are dark-skinned.

Older individuals are at increased risk of vitamin D insufficiency (Omdahl, Am J Clin Nutr 1982; Holick, J Clin Endocrinol Metab 2005; van der Wielen RP, Lancet 1995), particularly the very old (Passeri, J Clin Endocrinol Metab 2003). This may be due to a variety of factors, including reduced time outdoors with reduced skin exposure to the sun. This is *not* due to an impaired ability to produce vitamin D from sunlight, which had been erroneously suggested by a report in 1985 based solely on surgically-removed skin samples (MacLaughlin J, J Clin Invest 1985). A study found that exposing the backs or entire bodies of old and young people to equal amounts of light produced the same amounts of vitamin D (Davie, Clin Sci 1980). This was demonstrated again in a study among 10 older adults (average age 70) and 11 younger individuals (average age 30), which showed that older individuals do *not* have significantly lower skin concentrations of this vitamin D precursor than younger adults, and both groups showed similar increases in blood levels of 25(OH)D3 (the form of 25(OH)D obtained from skin production) at 24 hours after exposure to UV light (Borecka, Nutrients 2024).

People who are obese also tend to have a low plasma concentration of 25-hydroxyvitamin D, as subcutaneous fat may sequester the vitamin.

Because vitamin D is a fat-soluble vitamin, **people with reduced ability to absorb fat in the gut** may require higher doses when supplementing with vitamin D.

People who intentionally avoid sun exposure for long periods of time may need vitamin D supplementation.

Getting Vitamin D from Sunlight

UVB light from the sun, the primary wavelength of light that can cause sunburn and contribute to sun cancer, is necessary for the synthesis of vitamin D in the skin. However, just ten to fifteen minutes of sun exposure at least two times per week to the face, arms, hands, or back without sunscreen is usually sufficient to provide adequate vitamin D. It has been estimated that getting the equivalent of a 1,000 IU dose of vitamin D requires exposing the face, hands and arms to full sunlight at noon for 6 to 15 minutes in Miami or 9 to 19 minutes during ***non-winter months*** *in Boston, based on a darker-skinned Caucasian. Times are shorter by about 33% for people with very fair skin and double for those with dark skin. To get only 400 IU, times would be 40% as long.*

In ***winter months*** *in northern climates of the U.S., when a majority of the skin is covered (only hands and head exposed), it is estimated that one would need to be outside in the middle of the day, every day, for more than 60 minutes to maintain adequate levels of vitamin D (Elliott, Photochem Photobiol 2023).*

A study in Turkey among 40 nursing home residents (average age 76), slightly less than half of whom had low blood levels of vitamin D (< 20 ng/mL), found that sunlight exposure (at 40° north latitude, similar to Boulder, Colorado and Philadelphia) significantly increased vitamin D blood levels — measured as 25(OH)D. Among the residents who received sun exposure without sunscreen for about 20 minutes per day, five days per week, to approximately 33% of the body (hand, face, neck, forearms and lower legs) for one month during summer, levels increased from 24 ng/mL to 32 ng/mL, in contrast to little change in residents who did not receive this sun exposure. Participants were advised to get their sun exposure between 10:30 and 11:30 am to avoid the hottest times of the day. It's worth noting that all of the participants had light or fair skin. As noted earlier, longer sun exposure times may be needed to raise vitamin D levels in people with darker skin (Okan, J Clin Densitom 2021).

Sun exposure *cannot* cause toxic levels of vitamin D because excessive exposure to sunlight degrades *pre*vitamin D3 (which is normally converted by sunlight into vitamin D3 in the skin) and degrades vitamin D3 itself (Holick, N Engl J Med 2007). In fact, a study in which Caucasian subjects with more than sufficient levels of 25-hydroxyvitamin D (the form of vitamin D commonly measured in blood tests), averaging 33 ng/mL, were exposed to full midday sun in shorts (and, for women, sports bras) on their backs for 15 minutes and stomachs for another 15 minutes, levels of vitamin D in the blood increased significantly, but there was no increase in levels of 25-hydroxyvitamin D, and subjects with particularly high starting levels of vitamin D in their blood showed no increase in these levels with sun exposure. Older people in the study produced somewhat less vitamin D than younger people but the difference was not statistically significant (Chalcraft, Nutrients 2020).

Increased awareness about skin cancer has caused people to avoid the sun or use **sunscreen**. Concern has been raised as to whether the use of sunscreen causes a potential risk of reduced vitamin D, but this does not appear to be a significant issue. One study suggested that use of a low SPF sunscreen may provide protection from sun damage while still allowing enough UVB exposure for the body to synthesize vitamin D, although it's important to note that the study was funded by the makers of the sunscreen used in the study (Walgreens Boots Alliance Inc.). The study showed that in fair-skinned adults (average age 35) with sufficient blood levels of vitamin D who were outside for approximately 5 ½ hours per day for one week, consistent use of one of two sunscreens each with a sun protection factor (SPF) of 15 but having either low or high UVA protection prevented sunburn and resulted in modest average increases in blood levels of vitamin D (5 ng/mL with the low UVA formula and 8 ng/mL with the high UVA formula). (Note: Higher UVA formulas allow more UVB light, which, as noted above, is needed for vitamin D synthesis) (Young, Br J Dermatol 2019).

Furthermore, an observational study among 3,418 people ages 20 and older (average age 40) across the U.S. found that frequent **sun protective behaviors** — including wearing long sleeves, staying in the shade, and/or using sunscreen "most of the time or always" when going outside for more than one hour — was *not* associated with reduced total, upper body, or lower body bone mineral density or increased risk of osteoporotic bone fractures compared to rare sun protective behaviors. Blood levels of vitamin D were not assessed in this study (although dietary intake of vitamin D appeared to be similar across the groups), and strength, type and amount of sunscreen used were not reported (Afarideh, JAMA Dermatol 2021).

Similarly, an observational study in the U.S. among 1,213 healthy, non-Hispanic white adults (average age 43) found no association between frequent application of sunscreen or frequent staying in the shade and risk of vitamin D deficiency (defined as 25(OH)D levels <20 ng/mL). Although people who frequently wore long-sleeved shirts to avoid sun exposure had a 232% higher risk of vitamin D

deficiency compared to those who never wore long sleeved shirts, people who *occasionally* wore long sleeves to avoid sun exposure did *not* have an increased risk (Patel, Photodermatol Photoimmunol Photomed 2022).

(For information about choosing a sunscreen, including our comparisons of popular brands, see our article **What is the best sunscreen?**)

However, a study among adults aged 20 to 49 years with moderately dark skin in Korea who had vitamin D levels below 20 ng/mL found that 30 minutes of daylight to the hands, arms, and legs (while protecting the face and neck) three times a week for four weeks in the summer only raised levels by an average 0.9 ng/mL. Another group instructed to block as much sunlight as possible (with sunscreen and protective clothing) had an average decrease of -0.7 ng/mL, while a third group whose members did the same but took 600 to 800 IU of vitamin D daily had an average increase of 3.5 ng/mL. The researchers concluded that the amount of sun exposure in the first group -- although similar to some standard recommendations -- was inadequate for this population (Lee, J Korean Med Sci 2020).

Getting Vitamin D from Foods

Fortified foods

Fortified milk typically provides 100 IU of vitamin D per cup, and vitamin D may be added to other foods, including yogurt, orange juice, plant-based milk, and margarine. The maximum amount of vitamin D allowed in breakfast cereals was increased by the FDA on January 5, 2023 to 560 IU (14 mcg) of D3 (up from 350 IU) per 100 grams, and the amount allowed in grain-based nutrition bars was increased to 400 IU (10 mcg) of D3 (up from 90 IU) per 100 grams. This action was taken in response to a petition filed by Kellogg Company in 2019 (Federal Register Number 2022-28428, 1-5-23).

Fish

Fatty (oily) fish are also good sources of vitamin D. For example, you can get significant amounts of vitamin D from a 3-ounce (85 gram) serving of canned sockeye salmon (17.9 mcg or 716 IU) and canned pink salmon (12.3 mcg or 492 IU), as well as smaller amounts from light tuna (e.g., skipjack or yellowtail) (5.7 mcg or 228 IU), sardine (4.1 mcg or 164 IU). (U.S. Dietary Guidelines 2015-2020). Interestingly, canned fish tends to provide more vitamin D than traditionally cooked fish (see our Review of Canned Fish).

Nevertheless, keep in mind that vitamin D, whether in supplements or foods like fish, is **best absorbed with consumed with a fatty meal**. This may explain why a study in Poland found that a daily serving of 25 grams of salmon (naturally containing about 5 mcg of vitamin D) was much more effective at maintaining blood levels of vitamin D in the autumn/winter if it was consumed as a 100-gram cooked sausage (16.7 grams of fat) rather than as cooked salmon (3.25 grams of fat) (Utri-Khodadady, Nutrients 2024).

A study of five types of freshwater fish and four saltwater fish commonly consumed in Thailand showed that the amount of **vitamin D tended to be higher in freshwater fish** (particularly those living in well-lit parts of open water rather than deeper or muddy areas) than saltwater fish. The greatest amount of vitamin D per 3.5-ounce serving was found in common silver barb (48.5 mcg), red Nile tilapia (31 mcg), and Nile tilapia (19.8 mcg), which were *not* among the fattiest (oiliest) fish, followed by striped snakehead (5.7 mcg), grey mullet (4.7 mcg), giant sea perch (3.3 mcg), black-banded trevally (3.0 mcg), short-bodied mackerel (2.9 mcg) and walking catfish (2.4 mcg). In general, **boiling fish resulted in the highest vitamin D levels, while grilling or frying led to modest reductions**, with results dependent on the fish and cooking technique (Sridonpai, Foods 2022).

Other foods

Small amounts of vitamin D are found in beef liver (about 0.17 to 1.2 mcg per 3-ounce serving), cheese (up to 0.85 mcg per 3-ounce serving), and egg yolks (0.7 to 1 mcg per yolk). Mushrooms *exposed to ultraviolet light* can provide vitamin D: A ½ cup of portabella mushrooms can provide 7.9 mcg, and 3.5 oz of button mushrooms can provide about 21.5 mcg. Mushrooms grown this way may be labeled "excellent source of vitamin D," but many mushrooms are not grown this way and, therefore, contain very little vitamin D

(Cardwell, Nutrients 2018). Be aware that cooking reduces vitamin D levels in mushrooms: boiled/steamed (9% to 63% decrease), baked (35% to 47% decrease), or fried (17% to 61% decrease), with cooking *time* reducing levels more significantly than *temperature* (Libenska, J Food Compos Anal 2025).

Animal-based products can also provide small amounts of calcifediol, the 25-hydroxylated form of vitamin D. For instance, you can get small amounts of calcifediol from a 3-ounce (85 gram) serving of beef liver (0.06 to 0.65 mcg), pork liver (0.37 mcg), and chicken thigh (0.17 mcg), as well as from egg yolk (0.09 to 0.14 mcg) and butter (about 0.1 mcg per tablespoon) (Schmid, Adv Nutr 2013).

Getting Vitamin D from Supplements

Before buying a vitamin D supplement, be aware that vitamin D can be obtained in sufficient amounts from exposure to sunlight and from foods.

Gummies vs. tablets

To enhance its absorption, it is **advisable to take vitamin D with a meal containing fats or oils**. However, if you take it only with water, you may absorb more vitamin D from chewing a gummy supplement than from swallowing a tablet, as demonstrated in a study funded by the makers of *VitaFusion* gummies (Church & Dwight). In the study, 31 participants who were not deficient in vitamin D consumed a single, very high dose (20,000 IU) of vitamin D3 either as eleven and three-quarters *VitaFusion* D3 gummies or four and three-quarters vitamin D3 tablets from *Nature Made*) with 8 oz. of water on an empty stomach 30 minutes before a standardized breakfast. Over a 48-hour period, average blood levels of vitamin D were found to be approximately twice as high with the gummies than the tablets (Wagner, Nutrients 2019). Possible reasons for the better absorption with the gummies were that only the gummies contained oils and this, plus chewing them, better stimulated the digestive process. Had the supplements been taken with a meal containing oils, the results for each would likely have been more similar to each other.

Oral Sprays

Vitamin D **oral sprays** are commercially available (although not legally, as sprays are not considered dietary supplements) and have been promoted as an alternative for people with gastrointestinal issues (such as Crohn's disease, ulcerative colitis and steatorrhea) which can reduce intestinal absorption of vitamin D. This is based on the premise that sprayed vitamin D can be absorbed directly through the lining of the mouth. However, there do not appear to be studies proving that oral absorption actually occurs. Nevertheless, sprays can certainly work as well as any other type of oral delivery, possibly because one is still swallowing the liquid. In fact, a small study in India in people having various bowel diseases and very low levels of vitamin D found that 1,000 IU of vitamin D3 given as an oral spray daily for one month significantly increased blood levels of vitamin D (by an average of 10.5 ng/mL) compared to the same dose of D3 taken as a softgel (which resulted in an average increase of 4 ng/mL) (Satia, Nutr J 2015). In the same study, vitamin D3 spray also significantly increased vitamin D blood levels of healthy people compared to supplementation with the softgel — resulting in average increases of 8 ng/mL and 4 ng/mL, respectively. However, this may not have been a fair comparison, since both the spray and capsules were taken 30 minutes *following a meal*. This is not an ideal way to take vitamin D from a pill, which should be taken *with* a meal for best absorption -- and properly taking 1,000 IU of vitamin D as a softgel daily should increase blood levels by about 10 ng/mL in a lean individual.

A study in Ireland compared 3,000 IU of vitamin D given daily to healthy adults as an oral spray (*DLux3000* from Better You, UK, which includes lecithin -- a fat) or as a capsule. After 4 weeks, the spray and capsule were found to increase vitamin D levels, respectively, by 10.6 ng/mL and 12.2 ng/mL, with the difference between the two not statistically significant. No instruction was given to take either formulation at the time of a meal, perhaps explaining the modest increases despite the large dose (Todd, Br J Nutr 2016). A 6-week, placebo-controlled trial in England also found that 3,000 IU of vitamin D per day given as a spray resulted in similar increases in blood levels of vitamin D as the same dose given as a capsule. Average blood levels increased by about 16.3 ng/mL with both the capsules and the spray. Two participants reported the formation of small blisters on the cheek and tongue, one of whom discontinued the study -- although the researchers did not specify if this occurred in those given the spray or capsules, they did note that only 86% of the spray group was fully compliant versus 96.4% of the capsule group. As in the study above, participants were not instructed to take the

capsules or spray with a meal. The vitamin D spray was provided by Better You, which funded the study (Williams, Eur J Clin Nutr 2019). Sprays tend to be more expensive: about 8 to 10 cents per 1,000 IU dose. The same dose can be obtained from a vitamin D liquid drop or pill for little as 1 or 2 cents as shown in this Review.

In short, in healthy individuals, non-sprays can be as effective as sprays and are less expensive. In people with intestinal absorption problems, either may raise vitamin D levels but absorption may be greater with a spray.

Other tips when buying supplements:
When buying vitamin D, be aware that it is measured in International Units (IU) of vitamin D activity or as micrograms (mcg) of cholecalciferol (D_3) or ergocalciferol (D_2). 10 mcg = 400 IU.

Some calcium supplements contain the trace mineral boron, typically in amounts ranging from less than 1 mg up to about 6 mg per daily serving. Some, but not all evidence suggests that boron may reduce calcium loss in the urine, especially when magnesium intake is low (Neilson, FASEB J 1987). Although some preliminary research suggests boron supplementation in doses of 3 mg to 10 mg per day may be helpful for osteoarthritis and osteoporosis, one small trial found no increase in spine or thigh bone mineral density in postmenopausal women who took 3 mg of boron daily for one year compared to placebo (Biquet, Osteoporos Int 1996). Americans typically get an average of about 1 mg to 1.25 mg of boron daily from foods such as leafy vegetables, raisins, prunes, non-citrus fruits like apples, and some grains (Rainey, J Am Diet Assoc 1999). There is no established daily requirement for boron, but there is a Tolerable Upper Intake Level of 20 mg for per day for adults. Be aware that even at doses of 3 mg to 10 mg daily, boron may increase estrogen levels in both women and men (Neilson, FASEB J 1987; Naghii, Biol Trace Elem Res 1997). This may be of particular concern for women on hormonal therapy or those with a history of estrogen-sensitive cancer.

A small news article appeared in 2010 regarding research on the content of vitamin D supplements presented at a Multiple Sclerosis conference by a team at Johns Hopkins University. The results showed the mean actual dose in 10 supplements to be only 33.5% of the labeled dose, with a range from 0.24% to 81.7%. ConsumerLab.com contacted the research team to learn more about the findings. We spoke with Dr. Norman Haughey who oversaw the testing. It appears that the report was preliminary: The team had not yet performed extraction efficiency testing, i.e., making sure that they got all of the vitamin D out of the tested samples. Poor extraction recovery will yield low results and is a well-known problem with vitamin D in supplements where other components of the product can interfere with measurements.

What to Consider When Using:

In November 2010, recommended intake levels of vitamin D for Americans and Canadians were increased by the Institute of Medicine (IOM). For infants up to 12 months of age, the daily Adequate Intake (AI) was set at 400 IU (10 micrograms). Note that the AI is only relevant if an infant is not getting adequate exposure to sunlight. The following Recommended Dietary Allowances (RDAs) were established for other age groups: 600 IU (15 micrograms) for people aged 1 to 70 and 800 IU (20 micrograms) for those aged 71 and older (Food and Nutrition Board 2010). Confusing matters is that the FDA uses somewhat different daily amounts to establish the "Daily Values" in the "%DV" figures appearing in Supplement Facts panels on labels. For decades, the Daily Value for vitamin D for adults and children ages 4 and older was set at 400 IU (which turned out to be too low) and, in 2016, the FDA announced that the DV is now 800 IU (which is higher than necessary for most people).

While some studies suggest that even higher intakes of vitamin D may be useful for a range of purposes, the IOM considered the data behind those suggestions preliminary. Nevertheless, based on studies that showed a decreased risk of cancer associated with increased vitamin D intake and/or blood levels, the Canadian Cancer Society recommends a daily intake of 1,000 IU for adults in the fall and winter. The Canadian recommendation reflects the fact that there is reduced sun exposure in northern latitudes. The recommendation is for 1,000 IU intake year-round for people who are older, have dark skin, don't go outside often, or wear clothing that covers most of their skin.

In infants, the IOM and American Academy of Pediatrics recommend a vitamin D target level of 20 ng/dL. Both organizations recommend 400 IU daily to achieve this level (Wagner, Pediatrics 2008). A convenient way to give this is to add a single 400 IU drop of a liquid vitamin D, such as *Carlson Baby's Super Daily D3* — 400 IU per drop, to bottled milk per day. [**Note**: We tested and Approved this product in 2022, but, in this Review, we tested two, higher-dose *Carlson* liquids that would *not* be appropriate for regular use with infants or children.] Supplementation should occur even if children are breastfed -- particularly if breastfeeding continues for more than one year: A study in Canada found that without supplementation, the probability of breastfed children being vitamin D deficient was 16% by age 2 and 29% by age 3 (Darmawikarta, Am J Pub Health 2016).

Some groups suggest higher levels in infants of 30-60 ng/dL, however, this is controversial (Endo Soc, J C Endrocrinol Metab, 2011; Can Paed Soc Paediatr Child Health 2007). A clinical study shows that 400 IU of vitamin D3 daily was adequate to achieve the target level of 20 ng/dL in 97.5% of healthy, breastfed infants after 3 months of treatment. Higher doses were also studied (800 IU, 1200 IU, and 1600 IU daily). The 1600 IU dose caused excessively high levels in many infants. Additionally, there was no difference in bone mineral content between the lower and higher doses after a year of treatment (Gallo, JAMA 2013). These data confirm that 400 IU daily is an adequate dose for most healthy infants. Higher doses should be used cautiously. See Concerns and Cautions.

For building bone in young girls (ages 9 to 13), a study found benefit with a supplement providing, on a daily basis, 800 mg of calcium (from calcium citrate and calcium carbonate), 400 IU of vitamin D_2, and 400 mg of magnesium (from magnesium citrate) when taken regularly for six months (Greene, Osteoporosis Int 2011). The supplement (*Active Calcium Chewable*, USANA Health Sciences, Inc. - not tested in this Review) was taken as four chewable tablets, two with breakfast and two with dinner as it is best to divide doses when taking large amounts of minerals. Another study found that a weekly dose of 1,400 IU or 14,000 IU of vitamin D_3 resulted in significant increases in the mineral content of hip bones -- although the majority of the girls started the study deficient in vitamin D. Interestingly, the higher weekly dose appeared to have somewhat less effect than the lower dose (Al-Shaar, Bone 2013).

For reducing the risk of fracture of the hip and nonvertebral bone in people 65 years of age or older, maintaining a serum vitamin D level above 24 ng/mL appears to be beneficial (Bischoff-Ferrari, N Engl J Med 2012).

For reducing the risk of cardiovascular disease and stroke in men, 600 IU or more of vitamin D per day from food and supplements may be helpful. (A similar cardiovascular benefit in women has not been shown) (Sun, Am J Clin Nutr 2011).

For reducing high blood pressure in people already taking a calcium channel blocker (nifedipine), 2,000 IU of vitamin D_3 per day has been shown reduce systolic and diastolic pressures by a few points (Chen, Atherosclerosis 2014). However, a study giving 100,000 IU of vitamin D_3 quarterly showed no benefit (Witham, JAMA 2013) and a review of 46 studies concluded that vitamin D appears ineffective for lowering high blood pressure (Beveridge, JAMA Int Med 2015).

For improving cholesterol levels in people already taking a statin medication, 2,000 IU of vitamin D_3 per day has been shown to be effective, particularly among people with lower blood levels of vitamin D (Qin, Clin Nutr 2015).

For improving balance and muscle strength in older adults 800 to 1,000 IU daily of vitamin D may be beneficial (Muir, J Am Geriatr Soc 2011). (Cangussu, Osteoporos Int 2015).In older women deficient in vitamin D, 4,000 IU daily of vitamin D_3 has been shown to increase muscle fiber size, although not physical functioning (Ceglia, J Clin Endocrin Metab 2013).

For reducing symptomatic pain in fibromyalgia, 2,400 IU of vitamin D_3 for people with vitamin D levels below 24 ng/mL, and 2,400 IU for those starting with levels between 24 ng/mL and 32 ng/mL have been successfully used (although treatment was stopped as a precaution when levels exceeded 48 ng/mL, which occurred with several patients) (Wepner, Pain 2013).

For reducing menstrual pain in women, a single high dose of 300,000 IU vitamin D_3 taken 5 days before the start of menstruation may be beneficial for the following two months (Lasco, Arch Intern Med 2012). However, there are potential concerns with such a high dose (see Concerns and Cautions).

During pregnancy, raising vitamin D blood levels to 32 ng/mL in a population with a high rate of vitamin D deficiency decreased by half the incidence of pre-term labor, pre-eclampsia, and/or gestational diabetes. Women were given vitamin D starting at week 20 and dosage depended on initial vitamin D status, ranging from one dose of 60,000 IU to monthly doses of 120,000 IU for two to four months (Sablok, Clin Endocrinol 2015).

For reducing the risk of exacerbations of COPD, 100,000 IU of vitamin D monthly or 120,000 IU every two months has been helpful among people deficient in vitamin D (Martineau, Lancet Resp Med 2014; Lehouck, Ann Intern Med 2012).

D_2 or D_3?

Vitamin D can be found in dietary supplements in the D_2 or D_3 form. A number of studies have compared the abilities of vitamin D_2 and vitamin D_3 to raise vitamin D blood levels. Some have found them equally effective, and some have found D_3 more effective (Armas, J Clin Endocrinol Metab 2004; Trang, Am J Clin Nutr 1998; Holick, J Clin Endocrinol Metab 2008; Biancuzzo, Am J Clin Nutr 2010). As either form can be obtained inexpensively, it seems prudent to use supplements containing the D_3 form, particularly as D_2 may cause erroneously low vitamin D blood test results. The potential advantage of D_3 was illustrated in a small, but well-controlled, study in New Zealand in which 1,000 IU of vitamin D_2 or D_3, or a placebo, was given to healthy, non-obese individuals (ages 18 to 50) from the end of summer to the end of winter (Logan, Br J Nutr 2013). On average, vitamin D levels dropped 18 ng/mL among those taking placebo and 8 ng/mL among those taking vitamin D_2, while those taking D_3 maintained their levels (at 32 ng/mL). It's worth noting that, unlike the U.S., there is little vitamin D fortification of milk or other foods in New Zealand. Also, due to the relatively high latitude of the study region (46° — similar, for example, to Portland, Oregon) sunlight was relatively limited during the period of the study. Consequently, the dose of vitamin D_3 given may have been greater than needed to maintain vitamin D levels in similar individuals in much of the U.S. A large study among women in England, which used a lower dose — 600 IU per day, also demonstrated vitamin D_3 to be superior to D_2. In this study, which occurred during winter months, 12 weeks of supplementation with D_3 raised blood levels by 73% compared to only 34% for vitamin D_2. The researchers speculated that the greater effect of D_3 may be due to 1) a possible shorter half-life in the body of D_2 than D_3, and 2) the fact that each form has been shown to reduce levels of the active 25(OH)D form of the other but, since only D_3 is naturally found in the body, D_2 may have more of a negative effect on total blood levels (Tripkovic, Am J Clin Nutr 2017).

D_3 or Calcifediol?

Vitamin D_3 may be the preferred supplement form of vitamin D for raising 25(OH)D levels compared to vitamin D_2, but calcifediol, a 25-hydroxylated form of vitamin D, may be even more effective than vitamin D_3. Most research shows that calcifediol is about three to five times more potent for increasing 25(OH)D levels than vitamin D_3 when taken by mouth. The rate of absorption of calcifediol has also been shown to be higher than that of vitamin D_3. While 25(OH)D levels increase by about 0.7 to 1 ng/mL for every 100 IU of vitamin D_3 taken *when vitamin D levels are low*, the rate of absorption decreases as 25(OH)D levels rise. On the other hand, the absorption of calcifediol is linear, meaning that the rate of absorption does not decline as blood levels of 25(OH)D increase (Cesareo, Nutrients 2019). Unlike vitamin D_3, however, calcifediol is available only as a prescription drug in the U.S. and not as a supplement. Similarly, calci*triol*, the active hormone form of vitamin D formed in the body from calcifediol, is also available only as a prescription drug in the U.S. However, animal-based foods may contain calcifediol, as it is found in animal muscle and adipose (fat) tissue (Taylor, J Nutr 2014).

How Much Do You Need and "How Much is Too Much?"

After being ingested, both vitamin D_2 and D_3 are metabolized in the liver to form 25-hydroxy vitamin D and in the kidneys to 1,25-hydroxy vitamin D. Total serum levels (sometimes referred to as "blood levels") of 25-hydroxyvitamin D (also referred to as 25-(OH)D) are commonly used clinically to evaluate vitamin D status.

Based on the latest recommendations of the Institute of Medicine (IOM), the Estimated Average Requirement (EAR) for vitamin D among individuals ages 1 to 70 for bone growth and maintenance is daily intake of 400 IU of vitamin D, assuming minimal to no sun exposure, corresponding to a blood level of vitamin D (known as serum 25-(OH)D levels) of just 16 ng/mL. Some people will need more than this "average" requirement" so the IOM calculated an amount which would satisfy the requirements of practically all (97.5%) individuals; this amount, the **Recommended Daily Allowance (RDA), is 600 IU (15 mcg) of vitamin D, corresponding to a vitamin D**

blood level of 20 ng/mL. [Another way of expressing these levels is in nanomoles per liter (the unit of measurement commonly used in Canada): 1 ng/mL = 2.5 nmol/L, so 20 ng/mL = 50 nmol/L and 30 ng/mL = 75 nmol/L]. **For individuals over age 70, the RDA is 800 IU (20 mcg).**

From reviewing national surveys of blood levels, the IOM concluded that the majority of Americans and Canadians are getting enough vitamin D (as well as calcium), although elderly individuals are more likely to fall short on both and some adolescent girls may not get quite enough calcium. The IOM has determined that just 6% of U.S. population is vitamin D deficient (≤ 12.5 ng/mL), and 13% of Americans between the ages of 1 and 70 are "at risk" for vitamin D inadequacy (Manson, N Engl J Med 2016).

The IOM has cautioned that **vitamin D blood levels ≥ 50 ng/mL (and daily intakes above 4,000 IU) can put people at risk for adverse effects.** This is based on studies showing an increase in adverse events (including overall mortality, some cancers, cardiovascular disease, and fractures and falls) associated with serum 25-(OH)D levels starting at about 30 ng/mL to 48 ng/mL and higher (75 to 120 nmol/L). Examples of such adverse events include the following:

- **Overall mortality:** A population study following nearly a quarter million people in Denmark for three years found that vitamin D levels of 20 to 24 ng/mL were associated with the lowest risk of dying during the study. A high serum level (56 ng/mL) was associated with a 42% *higher* risk of dying during the study than people with a level of 20 ng/mL. (Durup, J Clin Endocrinol Metab 2012). Analysis of data from the UK Biobank based on over 307,601 adults of White European ancestry followed for 14 years found that the risk of dying from any cause decreased steeply as vitamin D levels increased from 10 ng/mL to 20 ng/mL, but there was no further decrease at higher levels. The odds of dying were estimated to be 25% higher at 10 ng/mL compared to 20 ng/mL (Sutherland, Ann Intern Med 2022). Oral supplementation with a dose of 60,000 IU (1,500 mcg) of vitamin D3 once per month for up to about 5 years was associated with a 29% *increased* risk of all-cause death compared to placebo in a study among 5,670 men and women (average age 64) in nine countries including Canada and India who were at increased risk of cardiovascular disease. In addition, supplementation did *not* reduce the risk of cardiovascular events, fractures and falls, or cancer occurrence (Joseph, Nutr Metab Cardiovasc Dis 2022).

- **Cancer-related death:** A large, 5-year, placebo-controlled study in Australia found that monthly, high-dose (60,000 IU) vitamin D3 did *not* reduce the risk of cancer-related death or death from any cause among men and women ages 60 to 84, most of whom already had more than adequate blood levels of vitamin D at the beginning of study. In fact, those given vitamin D had a 24% *increased* risk of cancer-related death during the last three years of the study, despite having higher average 25-(OH)D levels over the 5-year period (46 ng/mL vs. 30 ng/mL among those given the placebo) (Neale, Lancet Diabetes Endocrinol 2022). An analysis of data from the National Health and Nutrition Examination Survey (NHANES) found a 35% increase in the risk of cancer-related death and a 111% increase in all-cause death among people who already had sufficient blood levels of vitamin D (≥20 ng/mL) but were supplementing with more than 10 mcg (400 IU) of vitamin D per day (Chen, Ann Intern Med 2019).

- **Cardiovascular disease:** A population study following nearly half a million people aged 45 years and older for 4.5 years in Israel found that people with vitamin D levels of 20 to 36 ng/mL had the lowest risk of heart attack or death. Compared to people in this range, risk of heart attack and death was 91% higher among those with levels below 10 ng/mL, 26% higher among those with levels 10 to 20 ng/mL, and 13% higher when levels were above 36 ng/mL (Dror, J Clin Endocrinol Metab 2013). Furthermore, high doses of vitamin D do not appear to promote or protect against the development or progression of peripheral arterial calcification (hardening of the arteries), in people who already have sufficient levels (Billington, Osteopor Int 2020).

- **Bone density:** A study in Canada comparing the effects of different doses of vitamin D given daily for 3 years to adults with osteoporosis found that, compared to a dose of 400 IU per day, 4,000 IU and 10,000 IU *reduced* bone mineral density (BMD) in lower leg, and 10,000 IU *also reduced* BMD in the forearm. There were no significant differences bone strength for the different doses (Burt, JAMA 2019). A follow-up analysis showed that loss of BMD was *greater in women* than in men. After 3 years of treatment with 4,000 IU or 10,000 IU of vitamin D, BMD decreased in the forearms of women by 3.8% and 5.5%, respectively, compared to a nonsignificant reduction of 1.3% and 1.9%, respectively, in men. A similar, although smaller, loss of BMD in the lower leg also occurred in women taking higher doses of vitamin D but not in men. The average blood level of 25(OH)D after 3

years of treatment with 4,000 IU and 10,000 IU of vitamin D was 53 and 58 ng/mL, respectively, which are both above the vitamin D blood levels that the IOM has warned can put people at risk for adverse effects (Burt, J Bone Miner Res 2020).

- **Risk of falling:** A study comparing low-dose to high-dose vitamin D3, found that those achieving the highest blood levels fell about *twice as often* as those just above sufficiency (Bischoff-Ferrari, 2016).

Adverse effects of single, high doses

A possible explanation for why taking high-dose vitamin D has been linked with muscle weakness and increased risk of fractures and falls, comes from a study among professional athletes in Europe which found that a dose of 70,000 IU vitamin D_3 taken weekly for three months increased the production of an enzyme (24-hydroxylase) which *breaks down vitamin D* in the blood and *inactivates* the hormonally active form of vitamin D in the body. The increase in this enzyme persisted for up to 6 weeks after supplementation was discontinued (Owens, Med Sci Sports Exerc 2017). The researchers recommended that "*lower doses of vitamin D3 ingested frequently may be most appropriate and gradual withdrawal from supplementation as opposed to rapid withdrawal may be favorable*."

Giving an *extremely high* single dose (540,000 IU) of vitamin D orally to critically ill people deficient in vitamin D (averaging about 11 ng/mL) upon admission to intensive care units was *not* shown to reduce the risk of death in a large U.S. study involving over one thousand patients. In fact, within 28 days, 17.3% of those given vitamin D had died versus 13.1% of those given placebo. At 90 days, the values were, respectively, 23.5% and 20.6%. Deaths were particularly high with vitamin D versus placebo for those admitted with infections (28.4% vs. 19.9%) or sepsis (33.7% vs. 21.3%). Falls were also more frequent (7.1% vs. 5.3%). Due to the findings, the study was stopped before enrolling its target of 3,000 patients. Among those given vitamin D, levels rose to an average 46.9 ng/mL within three days (Nat Heart Lung Blood Inst, New Eng J Med 2019).

An Australian study among 22 men and women (ages 50 to 75), about two-thirds of whom had low (< 20 ng/mL) or deficient levels of vitamin D, found that adding a one-time 50,000 IU dose at the beginning of daily 1,000 IU dosing, did not raise vitamin D levels more than daily 1,000 IU alone over six weeks. For those who started the study with sufficient levels, the 50,000 IU dose appeared to *hamper* vitamin D increases during the final three weeks of the study. Both treatments equally increased circulating osteoprogenitor cells, which are involved in the formation of bone (Feehan, Exp Gerontol 2021).

The idea has been suggested that adverse effects of very high doses of vitamin D could be eliminated by also administering high doses of vitamins A and K (Masterjohn, Med Hypotheses 2007). This has not been proven and remains only a hypothesis.

It would seem prudent, based on the latest IOM recommendations and recent studies, to maintain blood levels of vitamin D above 20 ng/mL, but not much higher than 30 ng/mL. Misinterpretation and misapplication of the IOM reference standards can have adverse implications for patient care, including unnecessary vitamin D screening and supplementation. For healthy patients, routine screening is not recommended (Manson, N Engl J Med 2016).

With regard to the combination of vitamin D and calcium, an analysis of clinical trials involving older adults found a 9% lower risk of dying over a 3-year period among those who took vitamin D along with calcium supplementation (1,000 mg) compared to those not taking these supplements (Durup, J Clin Endocrinol Metab 2012). The benefit was only found with low dose (400 IU) and not higher dose (800 IU or more) vitamin D, and only with daily dosing as opposed to intermittent (e.g., annual) dosing of vitamin D. The benefit was not seen among people taking vitamin D without calcium, although this does not suggest a protective effect of calcium. It is difficult to draw useful conclusions for individuals from this study particularly because blood levels of vitamin D were not part of the analysis, i.e., it is possible that results would vary depending one's vitamin D status.

From reviewing national surveys of blood levels, the IOM concluded that the majority of Americans and Canadians are getting enough vitamin D (as well as calcium), although elderly individuals are more likely to fall short on both and some adolescent girls may not get quite enough calcium.

It should be noted that some researchers have set higher benchmarks for vitamin D sufficiency typically 30 ng/mL or above. For example, using 30 ng/mL as the benchmark for sufficiency and less than 15 ng/mL to define deficiency, a study of vitamin D levels concluded that 61% of American children and adolescents had insufficient levels of vitamin D and an additional 9% were deficient. Deficient children tended to have higher blood pressure and lower levels of HDL ("good") cholesterol than other children. Older children were more likely to be deficient, as were those who were obese, drank milk less than once a week, or spent more than four hours a day with TV, video, or computers. Those who used vitamin D supplementation were less likely to be deficient (Kumar, Pediatrics 2009).

When laboratories report your vitamin D level, they will typically show a "standard range" or "reference range" of about 20 ng/mL to 100 ng/mL. These ranges vary with the laboratory and are based on levels the lab has found in 95% of a "healthy" population. However, **these numbers do not reflect the range which has been recommended by the Institute of Medicine**, as described above, which falls at the lower end of this range. If your level is 25 ng/mL, for example, you should not interpret the results as suggesting that your level is low. Similarly, if your level is 60 ng/mL, this does not mean your level is ideal -- current evidence, as noted in the Review, suggests that it is too high.

A rule of thumb for raising serum levels of 25-hydroxyvitamin D is that about 100 IU of vitamin D_2 or D_3 daily will raise serum levels by about 1 ng/mL in adults and adolescents. However, more vitamin D is required by obese individuals to get this same increase: A study of obese adolescents found that about 200 IU was needed to for every 1 ng/mL increase in serum levels (Belenchia, FASEB J, 2011). Keep in mind, however, that there is diminishing benefit with doses of vitamin D above 1,400 IU (Cashman, Nutrients 2017). For example, at a daily dose of 600 IU, each 100 IU was found to increase blood levels by 1 ng/mL, but, at a daily dose of 3,750 IU, each 100 IU increased levels by only 0.41 ng/mL, according to a study of overweight/obese older adults in Lebanon (Bacha, J Clin Endocrinol Metab 2021).

Be aware that **people who begin supplementation with lower blood levels of 25-hydroxyvitamin D (< 20 ng/mL) may achieve approximately 60% greater increases** in levels than those who already have sufficient levels (> 20 ng/mL) when taking the same daily dose. This was shown in a 2-year study in people with type 2 diabetes taking a daily dose of 2,000 IU vitamin D3: Levels increased by 12 ng/mL when starting with a sufficient level, but by 19 ng/mL when starting with an insufficient level (Best, J Clin Endocrinol Metab 2021).

With moderate (1,000 IU per day) supplementation, it has been shown to take about 6 weeks for serum levels to reach their peak. For example, during winter with no significant sun exposure, supplementation with 1,000 IU has been shown to increase levels of around 20 ng/mL up to about 30 ng/ml at 6 weeks. In such a scenario, sun exposure or a dosage higher than 1,000 IU would be necessary to further elevate levels above 30 ng/mL (Kumar, Pediatrics 2009).

Exercise may help maintain vitamin D levels during winter

A study in England among 41 sedentary and overweight/obese but otherwise healthy men and women (average age 49) who were not taking vitamin D supplements showed that exercising for up to 40 minutes per day 4 times per week for 10 weeks during the winter (when vitamin D levels typically decline) prevented the decline in blood levels of the biologically active form of vitamin D -- 1,25(OH)2D3 -- compared to a 15% decline among participants who did not exercise. Those who exercised also had modestly smaller decreases in blood levels of vitamin D -- 25(OH)D (the precursor of 1,25(OH)2D3) -- compared to those who did not exercise, but the difference between groups was not statistically significant. Exercise sessions (including walking, running, or stationary cycling) were conducted indoors to avoid sunlight exposure as a confounding factor. Neither group had a decrease in weight or body fat (Perkin, Adv Sci 2025).

Magnesium affects vitamin D levels — make sure you get enough

Getting an adequate intake of magnesium helps maintain optimal blood levels of the prehormone form of vitamin D, 25(OH)D -- the form typically measured in blood tests. When 25(OH)D blood levels are around 30 ng/mL, magnesium boosts the conversion of vitamin D to 25(OH)D, raising levels by an average of 3 ng/mL. When levels are higher (about 30 to 50 ng/mL), magnesium actually lowers the amount of 25(OH)D by an average of about 7 ng/mL.

A study in Spain investigated the effects of magnesium supplementation (500 mg daily for two months) in postmenopausal women, many of whom had low dietary intakes of magnesium and and/or low blood or erythrocyte levels of magnesium, and most of whom had insufficient blood levels of 25-hydroxyvitamin D (< 20 ng/mL). At the end of the study, the women who supplemented with magnesium had significantly increased vitamin D levels (average increase 3 ng/mL) compared to those who took a placebo (Vázquez-Lorente, Nutrients 2020). Another study, among 78 overweight/obese men and women (average age 43) already getting about 300 mg per day of magnesium from their diets (which is somewhat less than the **recommended intakes**) and with adequate 25(OH)D levels (average 27 ng/mL) found that supplementation with 51 mg of magnesium (from magnesium glycinate) in addition to 1,000 IU (25 mcg) of vitamin D3 daily for 12 weeks increased 25(OH)D levels by about 6 ng/mL compared to an increase of only 2 ng/mL with vitamin D supplementation alone. Systolic blood pressure also decreased by an average of 7.5 mm Hg among those who began the study with higher systolic blood pressure (> 132 mm Hg) and took magnesium plus vitamin D, and this decrease was significant compared to similar participants in the placebo group, who did not take magnesium or vitamin D, but the decrease was not significant compared to vitamin D supplementation alone, and there was no significant decrease in diastolic blood pressure in any of the groups (Cheung, Nutrition 2022). (See **What It Does** for more about vitamin D supplementation and blood pressure).

Interestingly, with vitamin D2, a form not naturally made in the body, magnesium keeps boosting levels of the prehormone form, regardless of the level. This was demonstrated in a study of 180 adults in the U.S. (Dai, Am J Clin Nutr 2018).

To keep your vitamin D blood level in an optimal range, be sure you're getting an adequate amount of magnesium — many people don't. An additional 200 mg or so of magnesium will safely bring most people up to an adequate daily intake. You can get this from supplements or magnesium-rich foods, as discussed in our Magnesium Supplements Review.

Vitamin D Tests — Not Always Reliable

Tests to determine vitamin D levels may not always be reliable. Thousands of vitamin D readings taken in 2007 and 2008 turned out to be too high because the test was not properly performed. Newer, faster, and less expensive immunoassay tests are now widely used. However, a preliminary study found these devices to yield inaccurate results at least 40% of the time — tending to provide low results (Holmes, Am J Clin Pathol 2013). In the study, blood samples were run with an older established method (LC/MS) and two newer devices. The established method found vitamin D deficiency (less than 20 ng/mL) in 20% of the samples, but the Abbot Architect and Siemens Centaur-2 immunoassay devices respectively found deficiency in 28% and 44% of the samples, classifying some people as deficient who were not. The inaccuracies tended to occur with samples containing vitamin D2. If your test results don't seem to jive with your vitamin D intake and level of sun exposure, consider a retest using the LC/MS method, particularly if you are getting vitamin D2 from supplements or foods.

In people who are Black, the traditional measurement of vitamin D levels using *total* serum 25-hydroxyvitamin D may not be appropriate as it may overestimate vitamin D deficiency. Due to a genetic variant, many Blacks have lower levels of binding protein for vitamin D (which binds 85 to 90% of total vitamin D), allowing more of the total vitamin D to be bioavailable, i.e., available for use. Consequently, although total vitamin D levels may seem low in Blacks, the bioavailable amount of vitamin D may be sufficient. In fact, a study in Baltimore found mean total vitamin D levels to be 15.6 ng/mL in Blacks and 25.8 ng/mL in whites, while amounts of bioavailable vitamin D were the same in both groups. Furthermore, bone mineral density and calcium levels were higher among the Blacks than whites (Powe, NEJM 2013). ***The measurement of bioavailable vitamin D may, therefore, be more accurate for assessing the vitamin D status of Black individuals.*** Unfortunately, this is more difficult than measuring total vitamin D and currently relies on an indirect method in which vitamin D-binding protein must be measured and the amount of vitamin D bound to the protein is subtracted from total vitamin D.

Be aware that **exercise can temporarily raise vitamin D levels**. Moderate-intensity exercise (jogging on a treadmill for 60 minutes) was shown to increase blood levels of vitamin D (25(OH)D) in healthy men by about 2.4 ng/mL compared to resting conditions. Levels returned to normal after 1 hour. Theoretically, exercise might increase blood levels of vitamin D by causing vitamin D to be released from fat tissue or contracting skeletal muscles. Interestingly, blood levels of 1,25-dihydroxyvitamin D3 (the biologically active form of vitamin D) were significantly increased by about 7.28 pg/mL compared to resting conditions, and this difference remained significant

for at least 1 hour after exercise, although levels returned to baseline by 24 hours after exercise (Davies, J Physiol 2024). Based on these results, it may be prudent to **avoid exercising for at least one hour before blood testing for vitamin D**, as exercise may transiently increase results.

Take Vitamin D with Food

It is not uncommon for a person being treated for vitamin D deficiency to fail to achieve adequate serum levels. A small but striking study at the Cleveland Clinic Foundation Bone Clinic suggests that one reason may be that such people are taking vitamin D supplements on an empty stomach or with a small meal, usually breakfast or lunch (Mulligan, J Bone and Min Res 2010). In the study, 17 such people were instructed, instead, to take the same supplement with the largest meal of the day, usually supper. After 2 to 3 months, researchers found that serum vitamin D levels had increased, on average, by 56.7%. This magnitude of increase was seen across a wide range of vitamin D dosage and forms (D_2 and D_3). As vitamin D is fat soluble, it is generally recommended that it be taken with a meal containing fats. However, based on this study, it may be best to take vitamin D with your *largest* meal of the day, which is likely to contain the most fat. A more recent study re-emphasized this point. In this 1-day study, 50,000 IU of vitamin D3 was given with a breakfast that was fat-free or which included fats. Mean peak vitamin D blood levels (12 hours after taking the supplement) were 32% greater in subjects who took the supplement with a fat-containing meal than in those who took it with the fat-free meal. The ratio of monounsaturated to polyunsaturated fats in the meal did not matter (Dawson-Hughes, J Acad Nutri and Dietetics 2014). The researchers postulate that the presence of fat favors vitamin D absorption by stimulating the secretion of bile which promotes fat absorption.

Storage

After opening a bottle of a vitamin D supplement, exposing the contents to air, vitamin D will begin to lose activity over time. How fast this happens is largely a function of the *temperature* at which the open bottle is stored but can also be affected by exposure to light (which is why dark or opaque bottles are preferable) and the formulation of the product. At 77° F (25° C), this loss has been shown to range from just 5% to as much as 40% over a year. Refrigeration is typically not necessary unless you cannot keep the product at room temperature or you don't expect to fully use the contents by the "Best By" or expiration date. In these circumstances, consider refrigerating the product, as this may significantly slow the loss of potency (Temova, Eur J Hosp Pharm 2017).

Topical Vitamin D?

Preliminary clinical evidence indicates that vitamin D can be absorbed from a cream applied to the skin to raise blood levels of vitamin D.

A small study in Saudi Arabia among 48 young women (average age 23), many of whom had insufficient or deficient levels of vitamin D, showed that applying 1 gram (about ¼ teaspoon) of an aloe vera-based cream (*Top-D*) containing 5,000 IU of vitamin D daily for 90 days increased blood levels of vitamin D from 12.05 to 37.95 ng/mL, while those given the same amount of topical aloe vera alone showed no significant change in vitamin D levels. The cream also contained aromatic oils and glycerin to enhance permeation (Sadat-Ali, Int J Biomed Sci 2014). A subsequent, larger study by the same research group that included 537 men and women with low levels of vitamin D showed that applying the same dose of the same product for 4 months had similar benefit in raising blood levels of vitamin D. In this latter study, eleven of the individuals in the treatment group complained of skin irritation when first using the topical cream, but all continued with treatment (Bubshait, Clin Nutr ESPEN 2018). In the U.S., *Maxasorb D3* by Vita appears to have similar constituents as the cream used in the studies but at a lower concentration of vitamin D (1,000 IU per 1-gram dose), although it's an expensive way to get vitamin D at $19.95 for 60 doses, or 33 cents per dose — compared to as little as 1 to 6 cents from oral products.

Concerns and Cautions:

Excessive intake of vitamin D from supplements (i.e., doses of 50,000 IU weekly or more and/or doses causing blood levels >50 ng/mL, which can pose potential long-term risks), can cause **hypercalcemia** (too much calcium in the blood), with symptoms including constipation, headache, irritability, confusion, weakness, lower limb pain, fatigue, metallic taste, loss of appetite and significant weight

loss, painful calcium deposits, and kidney injury or kidney failure (de Paula, BMC Geriatrics 2020 with correspondence with ConsumerLab; Auguste, CMAJ 2019; Ferreira, Med Clin Res 2019; Van, Am J Sci 2017; Dudenkov, Mayo Clinic Proc 2015; Bohon, Clin Med Insights Womens Health 2013). To avoid hypercalcemia and other potential problems associated with higher blood levels of vitamin D, keep total intake of vitamin D from supplements and food under the established Tolerable Upper Intake Level (UL) above which the risk of harm increases. The ULs are 1,000 IU for infants up to 6 months, 1,500 IU for infants 6 months to 12 months, 2,500 IU for children 1 to 3 years, 3,000 for children 4 to 8 years, and 4,000 IU for all other people (Food and Nutrition Board 2010). Note: It is not thought to be necessary to factor in the amount of vitamin D produced by sun exposure when adding up total vitamin D intake. 4,000 IU daily, given for 6 months to obese adolescents who were deficient in vitamin D, was found to be safe (no hypercalcemia) as well as effective at raising vitamin D to sufficient levels (Belenchia, FASEB J 2011).

Women taking a daily calcium (1,000 mg) and vitamin D (400 IU) supplement showed a 17% greater incidence of **kidney stones** compared to women who did not receive the supplement (Wallace, Am J Clin Nutr 2011). The increased risk, however, is small, as only 0.35% of the women taking the calcium and vitamin D supplement reported kidney stones, compared to 0.30% of the women in the control group. A similar (17% to 20%) increase in kidney stones has been reported in studies with calcium supplementation alone, suggesting that calcium, rather than vitamin D, is the causative factor (Wallace, Am J Clin Nutr 2011). However, there is evidence that *very high-dose* vitamin D can markedly increase levels of calcium in the urine (hypercalciuria) from calcium supplementation, which, in turn, can increase the risk of kidney stones. A study of postmenopausal women who took either 600 IU or 10,000 IU of vitamin D_3 daily along with a calcium supplement (1,200 mg of calcium carbonate per day) for one year found that those who took the higher dose of vitamin D drove their vitamin D levels to an abnormally high average of 86 ng/mL and had *3.6 times the risk* of developing hypercalciuria (Aloia, Clin Endocrinol (Oxf) 2018).

Giving high-dose vitamin D (96,000 to 120,000 IU) every two months has been shown to increase the **risk of upper respiratory infections**, compared to taking a low dose (400 IU) daily (Martineau, Thorax 2015).

High-dose vitamin D may decrease the natural production of **melatonin** (a mediator of sleep). A small, but well-controlled study in people with multiple sclerosis being treated with interferon found that, after 3 months, those also given high dose vitamin D3 (800 IU daily plus 75,000 IU every 3 weeks — averaging 4,370 IU per day) had a significant decrease in nighttime melatonin production, while those given a low dose (800 IU daily) did not. The study continued for full year during which vitamin D levels in the both groups fell (possibly due to shorter days of winter), and, melatonin product began to increase toward original levels (Golan, Brain, Behav, Immun 2013). Consistent with this, a study found that among overweight, postmenopausal women given 2,000 IU of vitamin D daily for 12 months, those whose vitamin D blood levels rose to over 32 ng/mL showed a modest **deterioration of sleep quality** (6.2% reduction) compared to those with blood levels that remained below 32 ng/mL (5.7% improvement). The deterioration in sleep quality -- as well an increased need for sleep medication -- was also associated with larger increases in vitamin D blood levels. Most women started study with vitamin D levels ranging from about 16 to 27 ng/mL and all participated in a weight loss/exercise program as part of the study (Mason, Preventive Medicine, 2016).

The FDA has cautioned that some liquid vitamin D supplements are sold with droppers that could allow for excessive dosing of vitamin D to **infants**. It recommends that droppers hold no more than 400 IU of vitamin D to avoid this problem. It was reported that a 22-month-old girl whose pediatrician prescribed 400 IU (10 mcg) of vitamin D daily from 5 drops of a low-concentration liquid supplement was, instead, given 10,000 IU (250 mcg) per day from 5 drops of a liquid containing 2,000 IU (50 mcg) per drop. The error was identified after seven months, when she developed excessive thirst and urination, tiredness and decreased growth rate, and a vitamin D level above 200 ng/dL. Ultrasound imaging revealed a buildup of calcium salts in the kidney, likely compromising her kidney function (Pizzini, Front Pediatr 2024).

It is particularly important to avoid excessive vitamin D during **pregnancy**, as hypercalcemia in a mother can lead to seizures, mental and/or physical retardation, and other problems in an infant.

Giving high-dose vitamin D to people who are not vitamin D deficient may slightly **increase cholesterol levels**. A placebo-controlled study in Austria among older, generally overweight adults with hypertension but with vitamin D blood levels averaging 23.5 ng/mL found that giving 2,800 IU of vitamin D daily for 8 weeks resulted in slight but statistically significant *increases* in total cholesterol (+3.6 mg/dL) and triglycerides (+13 mg/dL) levels. (The average vitamin D level among those receiving vitamin D rose to 30.6 ng/mL.) The researchers speculated that high-dose vitamin D may cause increased calcium absorption from the gut, leaving less calcium to bind to (and remove) fats passing through the gut (Schwetz, J Clin Lipidol 2018). Similarly, increased triglyceride levels (+ 11 mg/dL) occurred in another study when participants with low blood levels of vitamin D (average 15 ng/mL) took 4,000 IU of vitamin D3 daily for six months, while those who took a lower dose (400 IU) actually had a slight decrease in triglycerides (- 6.2 mg/dL). There were no significant changes in total or LDL cholesterol with either dose. After six months, blood levels of vitamin D 25(OH)D among those taking the higher and lower dose had increased to an average of 30 ng/mL and 20 ng/mL, respectively (Miao, J Am Heart Assoc 2021).

Taking **elexacaftor/tezacaftor/ivacaftor (*Trikafta*)**, a prescription medication for cystic fibrosis, along with vitamin D may modestly increase the absorption of vitamin D, necessitating downward adjustment of vitamin D dosage. An analysis of data among 67 cystic fibrosis patients with pancreatic insufficiency (which impairs absorption of fat-soluble vitamins such as vitamin D) who were supplemented with very large doses of vitamin D (about 1,570 mcg or 63,000 IU per week, which is approximately 224 mcg or 9,000 IU per day) showed that, at 12 months after being prescribed treatment with elexacaftor/tezacaftor/ivacafter (*Trikafta*), vitamin D blood levels increased by about 5 ng/mL, requiring 28% of the patients to lower their maintenance dose of vitamin. This effect was attributed to the ability of *Trikafta* to improve pancreatic function, resulting in improved absorption of vitamin D (Wright, Pediatr Pulmonol 2021).

Long-term use of **proton-pump inhibitors (PPIs)**, which reduce stomach acid, was associated with lower blood levels of vitamin D and increased risk of vitamin D deficiency in a pilot study in Italy. The study, among 66 older adults — 30 of whom took 40 mg per day of the PPI pantoprazole (Protonix) and 36 of whom did not — found that 100% of those taking pantoprazole had vitamin D deficiency compared to only 25% of those who did not. Average blood levels of vitamin D were 15.5 ng/mL among pantoprazole users and 36.6 ng/mL among non-users. However, this difference could have been due, at least in part, to the older age of the participants in the PPI group, as older age has been linked with suboptimal blood levels of vitamin D (Losurdo, J Clin Med 2023).

High-dose estrogen-containing **oral contraceptives** (e.g., 30 mcg ethinyl estradiol plus 150 mcg levonorgestrel) may cause an increase in vitamin D binding protein, which regulates circulating levels of vitamin D. However, this does not seem to significantly affect total (bound and unbound) amounts of vitamin D in the blood, which is what most labs measure, and it is not clear if this effect has any clinical significance. Low-dose estrogen-containing oral contraceptives do not seem to have this effect (Stanczyk, J Steroid Biochem Mol Biol 2021).

For more information see the government report on vitamin D at https://ods.od.nih.gov/factsheets/vitamind.asp.

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Member: 905351 | Printed: 08/22/2025 11:27 a.m.