Dietary Supplement Fact Sheet: Vitamin D

Office of Dietary Supplements • Warren G. Magnuson Clinical Center • National Institutes of Health

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Posted Date:
5/27/2004

Updated:
7/14/2004 9:35:00 PM

What is vitamin D?

Vitamin D is a fat soluble vitamin that is found in food and can also be made in your body after exposure to ultraviolet (UV) rays from the sun. Sunshine is a significant source of vitamin D because UV rays from sunlight trigger vitamin D synthesis in the skin [1-2].

Vitamin D exists in several forms, each with a different level of activity. Calciferol is the most active form of vitamin D. Other forms are relatively inactive in the body. The liver and kidney help convert vitamin D to its active hormone form [3]. Once vitamin D is produced in the skin or consumed in food, it requires chemical conversion in the liver and kidney to form 1,25 dihydroxyvitamin D, the physiologically active form of vitamin D. Active vitamin D functions as a hormone because it sends a message to the intestines to increase the absorption of calcium and phosphorus [3].

The major biologic function of vitamin D is to maintain normal blood levels of calcium and phosphorus [3-4]. By promoting calcium absorption, vitamin D helps to form and maintain strong bones. Vitamin D also works in concert with a number of other vitamins, minerals, and hormones to promote bone mineralization. Without vitamin D, bones can become thin, brittle, or misshapen. Vitamin D sufficiency prevents rickets in children and osteomalacia in adults, two forms of skeletal diseases that weaken bones [5-6].

Research also suggests that vitamin D may help maintain a healthy immune system and help regulate cell growth and differentiation, the process that determines what a cell is to become [3,7,8].

What are the sources of vitamin D?

Food Sources

Fortified foods are common sources of vitamin D [4]. In the 1930s, rickets was a major public health problem in the United States (U.S.). A milk fortification program was implemented to combat rickets, and it nearly eliminated this disorder in the U.S. [4,9]. About 98% to 99% of the milk supply in the U.S. is fortified with 10 micrograms (ìg) (equal to 400 International Units or IU) of vitamin D per quart. One cup of vitamin

D fortified milk supplies one-half of the recommended daily intake for adults between the ages of 19 and 50, one-fourth of the recommended daily intake for adults between the ages of 51 and 70, and approximately 15% of the recommended daily intake for adults age 71 and over.

Although milk is fortified with vitamin D, dairy products made from milk, such as cheese and ice creams, are generally not fortified with vitamin D and contain only small amounts. Some ready-to-eat breakfast cereals may be fortified with vitamin D, often at a level of 10% to 15% of the Daily Value*. There are only a few commonly consumed foods that are good sources of vitamin D [4]. Suggested dietary sources of vitamin D are listed in Table 1.

Table 1: Selected food sources of vitamin D [10-12]

Food	International Units(IU) per serving	Percent DV*
Cod liver oil, 1 Tablespoon	1,360	340
Salmon, cooked, 3½ ounces	360	90
Mackerel, cooked, 3½ ounces	345	90
Tuna fish, canned in oil, 3 ounces	200	50
Sardines, canned in oil, drained, 1¾ ounces	250	70
Milk, nonfat, reduced fat, and whole, vitamin D fortified, 1 cup	98	25
Margarine, fortified, 1 Tablespoon	60	15
Pudding, prepared from mix and made with vitamin D fortified milk, ½ cup	50	10
Ready-to-eat cereals fortified with 10% of the DV for vitamin D, ¾ cup to 1 cup servings (servings vary according to the brand)	40	10
Egg, 1 whole (vitamin D is found in egg yolk)	20	6
Liver, beef, cooked, 3½ ounces	15	4
Cheese, Swiss, 1 ounce	12	4

*DV = Daily Value. DVs are reference numbers developed by the Food and Drug Administration (FDA) to help consumers determine if a food contains a lot or a little of a specific nutrient. The DV for vitamin D is 400 IU (10 µg) for adults. Most food labels do not list vitamin D content unless a food has been fortified with this nutrient. The percent DV (%DV) listed on the table above tells you the percent of the DV provided in one serving. A food providing 5% of the DV or less is a low source while a food that provides 10-19% of the DV is a good source and a food that provides 20% or more of the DV is high in that nutrient. It is important to remember that foods that provide lower percentages of the DV also contribute to a healthful diet. For foods not listed in this table, please refer to the U.S. Department of Agriculture's Nutrient Database Web site: http://www.nal.usda.gov/fnic/cgi-bin/nut_search.pl.

Sun exposure

Sun exposure is perhaps the most important source of vitamin D because exposure to sunlight provides most humans with their vitamin D requirement [13]. UV rays from the sun trigger vitamin D synthesis in skin [13-14]. Season, geographic latitude, time of day, cloud cover, smog, and sunscreen affect UV ray exposure and vitamin D synthesis [14]. For example, sunlight exposure from November through February in

Boston is insufficient to produce significant vitamin D synthesis in the skin. Complete cloud cover halves the energy of UV rays, and shade reduces it by 60%. Industrial pollution, which increases shade, also decreases sun exposure and may contribute to the development of rickets in individuals with insufficient dietary intake of vitamin D [15]. Sunscreens with a sun protection factor (SPF) of 8 or greater will block UV rays that produce vitamin D, but it is still important to routinely use sunscreen to help prevent skin cancer and other negative consequences of excessive sun exposure. An initial exposure to sunlight (10 -15 minutes) allows adequate time for Vitamin D synthesis and should be followed by application of a sunscreen with an SPF of at least 15 to protect the skin. 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 [14]. It is very important for individuals with limited sun exposure to include good sources of vitamin D in their diet.

What is the recommended intake for vitamin D?

Recommendations for vitamin D are provided in the Dietary Reference Intakes (DRIs) developed by the Institute of Medicine (IOM) of the National Academy of Sciences [4]. Dietary Reference Intakes is the general term for a set of reference values used for planning and assessing nutrient intake for healthy people. Three important types of reference values included in the DRIs are Recommended Dietary Allowances (RDA), Adequate Intakes (AI), and Tolerable Upper Intake Levels (UL). The RDA recommends the average daily intake that is sufficient to meet the nutrient requirements of nearly all (97-98%) healthy individuals in each age and gender group [4]. An AI is set when there is insufficient scientific data available to establish a RDA. AIs meet or exceed the amount needed to maintain a nutritional state of adequacy in nearly all members of a specific age and gender group. The UL, on the other hand, is the maximum daily intake unlikely to result in adverse health effects [4].

The IOM determined there was insufficient scientific information to establish a RDA for vitamin D. Instead, the recommended intake is listed as an Adequate Intake (AI), which represents the daily vitamin D intake that should maintain bone health and normal calcium metabolism in healthy people.

AIs for vitamin D may be listed on food and dietary supplement labels as either micrograms (µg) or International Units (IU). The biological activity of 1 µg vitamin D is equal to 40 IUs [4]. AIs for vitamin D for infants, children, and adults, are listed in table 2 in micrograms and IUs [4].

Table 2: Adequate Intake for vitamin D for infants, children, and adults [4]

Age	Children (µg/day)	Men (µg/day)	Women (µg/day)	Pregnancy (µg/day)	Lactation (µg/day)
Birth to 13 years	5 (=200 IU)				
14 to 18 years		5 (=200 IU)	5 (=200 IU)	5 (=200 IU)	5 (=200 IU)
19 to 50 years		5 (=200 IU)	5 (=200 IU)	5 (=200 IU)	5 (=200 IU)
51 to 70 years		10 (=400 IU)	10 (=400 IU)		
71+ years		15 (=600 IU)	15 (=600 IU)		

According to the IOM's report on the Dietary Reference Intakes for vitamin D, food consumption data suggest that median intakes of vitamin D for both younger and older women are below current recommendations [4]. Median intake refers to a statistical mid-point. Half of the population surveyed consumed more than the median intake while half consumed less. In this case, data suggest that more than 50% of younger and older women are not consuming recommended amounts of vitamin D.

In 2002, the vitamin D intakes of 1,546 non-Hispanic African American women and 1,426 non-Hispanic white women of reproductive age (15 to 49 years) were estimated by analyzing intake of milk and fortified cereals, two common dietary sources of vitamin D [16]. Blood levels of vitamin D were also examined in these groups. Data examined were from the National Health and Nutrition Examination Survey (NHANES) III survey, which interviewed people from randomly selected households all across the U.S. The prevalence of hypovitaminosis D, a term used to describe low blood levels of vitamin D, was 42.4% among African American women and 4.2% among white women. In both groups, blood levels of vitamin D were higher when milk or fortified cereals were consumed more than 3 times per week. Among African American women, the risk of hypovitaminosis D decreased as milk and fortified cereal intake increased. These numbers suggest that large numbers of African American women may not consume recommended amounts of vitamin D. More frequent intake of vitamin D fortified milk and fortified cereals may help prevent hypovitaminosis D in this group.

When can vitamin D deficiency occur?

Nutrient deficiencies are usually the result of dietary inadequacy, impaired absorption and utilization, increased requirement, or increased excretion (loss). A deficiency of vitamin D can occur [9]:

- when usual intake is below recommended levels
- when there is limited exposure to sunlight
- when the kidney cannot convert vitamin D to its active hormone form
- when someone cannot adequately absorb vitamin D from the digestive tract

Vitamin D deficient diets are associated with milk allergy, lactose intolerance, and strict vegetarianism. Infants fed only breast milk also receive insufficient amounts of vitamin D unless they also receive appropriate levels of vitamin D supplementation [17].

The classic vitamin D deficiency diseases are *rickets and osteomalacia*. In children, vitamin D deficiency causes rickets. Rickets is a bone disease characterized by a failure to properly mineralize bone tissue. Rickets results in soft bones and skeletal deformities [15]. Rickets was first described in the mid-17th century by British researchers [15,18]. In the late 19th and early 20th century, German physicians noted that consuming 1 to 3 teaspoons (3 teaspoons is equal to 1 tablespoon) of cod liver oil per day could reverse rickets [18]. The most common causes of rickets are vitamin D deficiency from a vitamin D deficient diet, lack of sunlight, or both. The recommendation to fortify milk with vitamin D made rickets a rare disease in the U.S. for many years. However, rickets has recently reemerged, in particular among African American infants and children [15,18]. In 2003, a report from Memphis, Tennessee, described 21 cases of rickets among infants, 20 of whom were African-American [18].

Prolonged exclusive breastfeeding without vitamin D supplementation is one of the most significant causes of the reemergence of rickets. Additional causes include extensive use of sunscreens and increased use of day-care, resulting in decreased outdoor activity and sun exposure among children [15,18].

Rickets is more prevalent among immigrants from Asia, Africa, and Middle Eastern

countries for a variety of reasons [15]. Among immigrants, vitamin D deficiency has been associated with iron deficiency, leading researchers to question whether or not iron deficiency may impair vitamin D metabolism [15]. Immigrants from these regions are also more likely to follow dress codes that limit sun exposure. In addition, darker pigmented skin converts UV rays to vitamin D less efficiently than lighter skin [15].

In adults, vitamin D deficiency can lead to osteomalacia, which results in muscular weakness in addition to weak bones [5-6,9]. Symptoms of bone pain and muscle weakness may indicate vitamin D deficiency, but symptoms may be subtle and go undetected in the initial stages. A deficiency is accurately diagnosed by measuring the concentration of a specific form of vitamin D in blood [9,14].

Who may need extra vitamin D to prevent a deficiency?

It can be difficult to obtain enough vitamin D from natural food sources. For many people, consuming vitamin D fortified foods and adequate sunlight exposure are essential for maintaining a healthy vitamin D status. In some groups, dietary supplements may be needed to meet the daily need for vitamin D.

Infants who are exclusively breastfed
In infants, vitamin D requirements cannot be met by human (breast) milk alone [4,19], which usually provides approximately 25 IU vitamin D per liter [20]. Sunlight is a potential source of vitamin D for infants, but the American Academy of Pediatrics (AAP) advises that infants be kept out of direct sunlight and wear protective clothing and sunscreen when exposed to sunlight [21]. The American Academy of Pediatrics (AAP) recommends a daily supplement of 200 IU vitamin D for breastfed infants beginning within the first 2 months of life unless they are weaned to receive at least 500 ml (about 2 cups) per day of vitamin D-fortified formula [20]. Children and adolescents who are not routinely exposed to sunlight and do not consume at least 2, 8-fluid ounce servings of vitamin D-fortified milk per day are also at higher risk of vitamin D deficiency and may need a dietary supplement containing 200 IU vitamin D [20].

Formula fed infants usually consume recommended amounts of vitamin D because the 1980 Infant Formula Act requires that infant formulas be fortified with vitamin D. The minimal level of fortification required is 40 IU vitamin D per 100 calories of formula. The maximum level of vitamin D fortification allowed is 100 IU per 100 calories of formula [22]. This range of fortification produces a standard 20 calorie per ounce formula providing between 265 and 660 IU vitamin D per liter.

Older adults
Americans age 50 and older are believed to be at increased risk of developing vitamin D deficiency [14]. As people age, skin cannot synthesize vitamin D as efficiently and the kidney is less able to convert vitamin D to its active hormone form [4,23-26]. It is estimated that as many as 30% to 40% of older adults with hip fractures are vitamin D insufficient [13]. Therefore, older adults may benefit from supplemental vitamin D.

Persons with limited sun exposure
Homebound individuals, people living in northern latitudes such as in New England and Alaska, women who wear robes and head coverings for religious reasons, and individuals working in occupations that prevent sun exposure are unlikely to obtain much vitamin D from sunlight. It is important for people with limited sun exposure to consume recommended amounts of vitamin D in their diets or consider vitamin D supplementation [27-29].

Persons with greater skin melanin content

Melanin is the pigment that gives skin its color. Greater amounts of melanin result in darker skin. The high melanin content in darker skin reduces the skin's ability to produce vitamin D from sunlight. It is very important for African Americans and other populations with dark-pigmented skin to consume recommended amounts of vitamin D. Some studies suggest that older adults, especially women, in these groups are at even higher risk of vitamin D deficiency [16,30]. Individuals with darkly pigmented skin who are unable to get adequate sun exposure and/or consume recommended amounts of vitamin D may benefit from a vitamin D supplement.

Persons with fat malabsorption
As a fat soluble vitamin, vitamin D requires some dietary fat for absorption. Individuals who have a reduced ability to absorb dietary fat may require vitamin D supplements [31]. Symptoms of fat malabsorption include diarrhea and oily stools [31]. Fat malabsorption is associated with a variety of medical conditions [9]:

Pancreatic enzyme deficiencyis characterized by insufficient secretion of pancreatic enzymes. Pancreatic enzymes are essential for fat absorption, and a deficiency of these enzymes can result in fat malabsorption.

Crohn's Disease is an inflammatory bowel disease that affects the small intestines. People with Crohn's disease often experience diarrhea and fat malabsorption.

Cystic Fibrosis (CF) is a hereditary disorder that causes the body to secrete a thick, sticky mucus. This mucus clogs the pancreas and lungs. People with CF often experience fat malabsorption.

Sprue, often referred to as Celiac Disease (CD), is a genetic disorder. People with CD are intolerant to a protein called gluten. In CD, gluten can trigger damage to the small intestines, where most nutrient absorption occurs. People with CD often experience fat malabsorption. They need to follow a gluten free diet to avoid malabsorption and other symptoms of CD.

Liver disease includes a wide variety of disorders that impair liver function. Some people with liver disease experience fat malabsorption.

Surgical removal of part or all of the stomach or intestines can impair digestion and absorption of many nutrients. Fat malabsorption can occur after this type of surgery.

What are some current issues and controversies about vitamin D?

Vitamin D and osteoporosis:
It is estimated that over 25 million adults in the United States have, or are at risk of developing, osteoporosis [32]. Osteoporosis is a disease characterized by fragile bones, and it significantly increases the risk of bone fractures. Osteoporosis is most often associated with inadequate calcium intake. However, a deficiency of vitamin D also contributes to osteoporosis by reducing calcium absorption [33]. While rickets and osteomalacia are extreme examples of vitamin D deficiency, osteopororsis is an example of a long-term effect of vitamin D insufficiency [34]. Adequate storage levels

of vitamin D help keep bones strong and may help prevent osteoporosis in older adults, in non-ambulatory individuals (those who have difficulty walking and exercising), in post-menopausal women, and in individuals on chronic steroid therapy [35].

Researchers know that normal bone is constantly being remodeled, a process that describes the breakdown and rebuilding of bone. During menopause, the balance between these two systems changes, resulting in more bone being broken down or resorbed than rebuilt. Hormone therapy (HT) with sex hormones such as estrogen and progesterone may delay the onset of osteoporosis. However, some medical groups and professional societies such as the American College of Obstetricians and Gynecologists, The North American Menopause Society, and The American Society for Bone and Mineral Research recommend that postmenopausal women consider using other agents to slow or stop bone-resorption because of the potential adverse health effects of HT [36-38].

Vitamin D deficiency, which is often seen in post-menopausal women and older Americans [4], has been associated with greater incidence of hip fractures [39-41]. In a review of women with osteoporosis hospitalized for hip fractures, 50 percent were found to have signs of vitamin D deficiency [35]. Daily supplementation with 20 µg (800 IU) of vitamin D may reduce the risk of osteoporotic fractures in elderly populations with low blood levels of vitamin D [42]. The Decalyos II study examined the effect of combined calcium and vitamin D supplementation in a group of elderly women who were able to walk indoors with a cane or walker. The women were studied for two years, and results suggested that such supplementation could reduce the risk of hip fractures in this population [43].

All women are encouraged to consult with a physician about their need for vitamin D supplementation as part of an overall plan to prevent and/or treat osteoporosis.

Vitamin D and cancer:
Laboratory, animal, and epidemiologic evidence suggests that vitamin D may be protective against some cancers. Epidemiologic studies suggest that a higher dietary intake of calcium and vitamin D, and/or sunlight-induced vitamin D synthesis, correlates with lower incidence of cancer [44-51]. In fact, for over 60 years researchers have observed an inverse association between sun exposure and cancer mortality [33]. The inverse relationship between higher vitamin D levels in blood and lower cancer risk in humans is best documented for colon and colorectal cancers [44-50]. Vitamin D emerged as a protective factor in a study of over 3,000 adults (96% of whom were men) who underwent a colonoscopy between 1994 and 1997 to look for polyps or lesions in the colon. About 10% of the group was found to have at least one advanced neoplastic (cancerous) lesion in the colon. There was a significantly lower risk of advanced cancerous lesions among those with the highest vitamin D intake [52].

Additional well-designed clinical trials need to be conducted to determine whether vitamin D deficiency increases cancer risk, or if an increased intake of vitamin D is protective against some cancers. Until such trials are conducted, it is premature to advise anyone to take vitamin D supplements for cancer prevention.

Vitamin D and steroids:
Corticosteroid medications such as prednisone are often prescribed to reduce inflammation from a variety of medical problems. These medicines may be essential for medical treatment, but they have potential side effects, including decreased calcium absorption [53-55]. There is some evidence that steroids may also impair vitamin D metabolism, further contributing to the loss of bone and development of

osteoporosis associated with long term use of steroid medications [54]. One study demonstrated that patients who received 0.25 µg of active vitamin D and 1000 mg calcium per day in addition to corticosteroid therapy after a kidney transplant avoided rapid bone loss commonly associated with post-transplant therapy [55]. For these reasons, individuals on chronic steroid therapy should consult with a qualified health care professional about the need to increase vitamin D intake through diet and/or dietary supplements.

Vitamin D and Alzheimer's disease:
Alzheimer's disease is associated with an increased risk of hip fractures [56]. This may be because many Alzheimer's patients are homebound, frequently sunlight deprived, and older. With aging, less vitamin D is converted to its active form [4]. One study of women with Alzheimer's disease found that decreased bone mineral density was associated with a low intake of vitamin D and inadequate sunlight exposure [57]. Physicians should evaluate the need for vitamin D supplementation as part of an overall treatment plan for adults with Alzheimer's disease.

Vitamin D and caffeine:
High caffeine intake may accelerate bone loss. Caffeine may inhibit vitamin D receptors, thus limiting absorption of vitamin D and decreasing bone mineral density. A study found that elderly postmenopausal women who consumed more than 300 milligrams per day of caffeine (which is equivalent to approximately 18 oz of caffeinated coffee) lost more bone in the spine than women who consumed less than 300 milligrams per day [58]. However, there is also evidence that increasing calcium intake (by, for example, adding milk to coffee) can counteract any potential negative effect that caffeine may have on bone loss. More evidence is needed before health professionals can confidently advise adults to decrease caffeine intake as a means of preventing osteoporosis.

What are the health risks of too much vitamin D?

Vitamin D toxicity can cause nausea, vomiting, poor appetite, constipation, weakness, and weight loss [59]. It can also raise blood levels of calcium [6], causing mental status changes such as confusion. High blood levels of calcium also can cause heart rhythm abnormalities. Calcinosis, the deposition of calcium and phosphate in the body's soft tissues such as the kidney, can also be caused by vitamin D toxicity [4].

Sun exposure is unlikely to result in vitamin D toxicity [60]. Diet is also unlikely to cause vitamin D toxicity, unless large amounts of cod liver oil are consumed. Vitamin D toxicity is much more likely to occur from high intakes of vitamin D in supplements. The Food and Nutrition Board of the Institute of Medicine has set the tolerable upper intake level (UL) for vitamin D at 25 µg (1,000 IU) for infants up to 12 months of age and 50 µg (2,000 IU) for children, adults, pregnant, and lactating women [4]. Long term intakes above the UL increase the risk of adverse health effects. Upper intake levels for vitamin D are listed in micrograms and International Units for infants, children, and adults in Table 3 [4].

Table 3: Tolerable Upper Intake Levels for vitamin D for infants, children, and adults [4]

Age	Men (µg/day)	Women (µg/day)	Pregnancy (µg/day)	Lactation (µg/day)
0 to 12 months	25 (=1,000 IU)	25 (=1,000 IU)		

1 to 13 years	50 (=2,000 IU)	50 (=2,000 IU)		
14 to 18 years	50 (=2,000 IU)	50 (=2,000 IU)	50 (=2,000 IU)	50 (=2,000 IU)
19+ years	50 (=2,000 IU)	50 (=2,000 IU)	50 (=2,000 IU)	50 (=2,000 IU)

Selecting a healthful diet

As the 2000 *Dietary Guidelines for Americans* state, "Different foods contain different nutrients and other healthful substances. No single food can supply all the nutrients in the amounts you need" [61]. For more information about building a healthful diet, refer to the *Dietary Guidelines for Americans* [61] http://www.health.gov/dietaryguidelines and the US Department of Agriculture's *Food Guide Pyramid* [62] http://www.usda.gov/cnpp/pyramid2.htm.

This Fact Sheet was published by the Clinical Nutrition Service, Warren Grant Magnuson Clinical Center, National Institutes of Health (NIH), Bethesda, MD, in conjunction with the Office of Dietary Supplements (ODS) in the Office of the Director of NIH. The mission of ODS is to strengthen knowledge and understanding of dietary supplements by evaluating scientific information, stimulating and supporting research, disseminating research results, and educating the public to foster an enhanced quality of life and health for the U.S. population. The Clinical Nutrition Service and the ODS would like to thank the expert scientific reviewers for their role in ensuring the scientific accuracy of the information discussed in this Fact Sheet.

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Disclaimer

Reasonable care has been taken in preparing this document and the information provided herein is believed to be accurate. However, this information is not intended to constitute an "authoritative statement" under Food and Drug Administration rules and regulations.

About ODS and The Warren Grant Magnuson Clinical Center

The mission of the Office of Dietary Supplements (ODS) is to strengthen knowledge and understanding of dietary supplements by evaluating scientific information, stimulating and supporting research, disseminating research results, and educating the public to foster an enhanced quality of life and health for the U.S. population.

The Warren Grant Magnuson Clinical Center is the clinical research hospital for NIH. Through clinical research, physicians and scientist translate laboratory discoveries into better treatments, therpaies and interventions to improve the nation's health.

General Safety Advisory

Health professionals and consumers need credible information to make thoughtful decisions about eating a healthful diet and using vitamin and mineral supplements. To help guide those decisions, registered dietitians at the Warren Grant Magnuson Clinical Center, the clinical research hospital at the National Institutes of Health (NIH) in Bethesda, MD, developed a series of Fact Sheets in conjunction with the Office of Dietary Supplements in the Office of the Director of NIH. These fact sheets provide responsible information about the role of vitamins and minerals in health and disease. Each Fact Sheet in this series received extensive review by recognized experts from the academic and research communities.

The information is not intended to be a substitute for professional medical advice. It is important

to seek the advice of a physician about any medical condition or symptom. It is also important to seek the advice of a physician, registered dietitian, pharmacist, or other qualified health professional about the appropriateness of taking dietary supplements and their potential interactions with medications.

Reviewers

The Clinical Nutrition Service and the ODS would like to thank the expert scientific reviewers for their role in ensuring the scientific accuracy of the information discussed in this Fact Sheet:

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