## Fat-soluble vitamins

Fat-soluble vitamins are defined as those that dissolve in fats and oils (“NCI Dictionary of Cancer Terms,” 2018). Due to this ability, fat-soluble vitamins can be stored in the body’s fatty tissue. However, they must also be absorbed along with fats in the diet, meaning that they are not easily absorbed without dietary fat present in ingestion (Dawson-Hughes et al., 2015; Gijsbers, Jie, & Vermeer, 1996). Fat-soluble vitamins are found in both animal and plant foods as well as in dietary supplements.

Vitamins A, D, E, and K are the fat-soluble vitamins. Because of their solubility, they are stored in the tissues of the body and play critical roles in metabolism and proper hormonal function.

Critical!

As dietary fat assists with the absorption of fat-soluble vitamins, it is critical that people are consuming fat in their diet. Consuming fat-blocking supplements impairs the body’s ability to absorb fat-soluble vitamins (Melia, Koss-Twardy, & Zhi, 1996). Furthermore, high doses of fat-soluble vitamins consumed over long periods can lead to toxicities as they are stored in tissues.

### Vitamin A

*What is it and why is it important?*

Vitamin A is a group of compounds referred to as retinoids. The most common retinoids are retinol, retinal, and retinoic acid. Vitamin A can also be made from beta-carotene and other similar compounds known as the carotenoids, which are antioxidants. Vitamin A plays several critical roles in human health (Figure: The Role of Vitamin A). It is critical in vision, immune function, and for human development. Vitamin A deficiency is known to lead to impaired vision and even blindness and death in extreme circumstances (Table: Forms and Functions of Vitamin A). While vitamin A deficiency is rare in developed countries, it has high prevalence in developing countries.

A person with text on it

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Roughly 33% of children under the age of 5 have vitamin A deficiency worldwide, with 670,000 children under 5 dying each year due to vitamin A deficiency and another 250,000 going blind (World Health Organization, 2013).

Research on vitamin A dates back to the 1940s, and, since then, there has been little evidence to indicate that vitamin A supplementation will improve one’s physical capabilities.

Forms and Functions of Vitamin A

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| --- | --- |
| Chemical | Description |
| Retinol | Retinol is often referred to as vitamin A1. It is converted into retinal in the human body. |
| Retinal | Retinal is one of the other main forms of vitamin A and is converted into retinoic acid in the human body. Retinal is important as it converts light into signals that the brain turns into vision. |
| Retinoic Acid | Retinoic acid directly affects expression of genes. Retinoic acid is often used as a treatment of some skin conditions, such as acne, as it can control protein production that contributes to acne. |

*Where is it found in foods?*

Vitamin A is found primarily in fish, specifically fish oils such as cod liver oil. It is also found in butter, eggs, some cheeses, and beta-carotene-rich foods such as carrots, squash, and kale.

*How do we apply this information?*

Vitamin A is consumed in adequate quantities when following a balanced diet that includes some seafood; dairy; green, leafy vegetables; and bright-coloured vegetables. In cases where vitamin A deficiency is a concern, a registered dietitian nutritionist can help with supplementation guidelines after the adequate dietary sources are incorporated regularly.

Coach's Corner

There does not appear to be any evidence to suggest that vitamin A supplementation improves athletic performance. For example, one study performed in 1942, in which participants were purposefully brought into a state of vitamin A deficiency and then given high doses of vitamin A for 6 weeks, saw no improvement in ability to perform on an incline treadmill test.

### Vitamin D

*What is it and why is it important?*

Vitamin D has been a subject of great discussion and investigation over the last several decades. Vitamin D plays many critical roles in human health, including immune function, bone formation, and calcium metabolism. One of the more well-known diseases that arises from vitamin D deficiency is rickets, which is one of the first diseases that was tied directly to a nutrient deficiency [(](https://paperpile.com/c/cZDv7y/lfvq8)McCollum et al., 1925[)](https://paperpile.com/c/cZDv7y/lfvq8). In humans, vitamin D can be manufactured in the body through the conversion of cholesterol (7-dehydrocholesterol) to the active form of vitamin D (D3) by sunlight.

It has previously been argued there is no need for dietary vitamin D or vitamin D supplementation (Antonio et al., 2009). However, recent evidence has indicated that dietary vitamin D and supplemental vitamin D are indeed necessary for many people.

Vitamin D insufficiency and deficiency is likely the result of individuals spending the majority of their time indoors or when they are outside, wearing sunblock or clothing that blocks the majority of the skin. Living at more northern latitudes and diets low in vitamin D-rich foods also contributes to deficiency. These low levels of vitamin D may impair some aspects of performance and recovery, specifically via reducing overall aerobic metabolism, muscle repair, and bone repair. There is some evidence that correcting these deficiencies can improve aerobic performance, muscle strength, and recovery from training (Dahlquist et al., 2015; Farrokhyar et al., 2015). However, more work is needed to determine how much benefit athletes may get from vitamin D supplementation.

*Where is it found in foods?*

Vitamin D is found in many of the same foods as vitamin A: salmon, sardines, mackerel, tuna, cod-liver oil, shiitake mushrooms, fortified milk, and fortified cheese.

Food for Thought

Vitamin D was first discovered in cod liver oil and has since been identified as an essential vitamin and an important nutrient for a variety of metabolic and biological processes.

*How do we apply this information?*

Of all the micronutrients, vitamin D has the highest rate of deficiency worldwide. Specific focus should be given to this micronutrient to ensure that there are not substantial deficiencies and to encourage more vitamin D-rich foods in the diet. Encouraging clients to ask their own doctor to add vitamin D to their normal labs is a wise idea as well to assess their own status. Then, the provider can make suggestions, as needed.

### Vitamin E

*What is it and why is it important?*

Similar to vitamin A, vitamin E is a class of compounds. The most common ones are known as the tocopherols and the tocotrienols, each of which has four types: alpha, beta, gamma, and delta (Shils, Shike, Ross, Caballero, & Cousins, 2006). Vitamin E is one of the main antioxidant molecules in the body and it protects cells from oxidative damage. One the main mechanisms by which vitamin E protects cells is by reducing the oxidation of fatty acids that make up cell membranes and other critical structures within cells (Meagher, Barry, Lawson, Rokach, & FitzGerald, 2001).

Vitamin E deficiency can lead to neurological disorders that include uncontrolled movement and slurred speech. Furthermore, vitamin E supplementation has been shown to be beneficial on lipid peroxidation and measures of oxidative damage even in otherwise healthy people (Meagher, Barry, Lawson, Rokach, & FitzGerald, 2001).

*Where is it found in foods?*

Vitamin E is primarily found in nuts and seeds (e.g., almonds, sunflower seeds, wheat germ, hazelnuts, and pine nuts) as well as oils derived from them. It is also found in fish, such as salmon, as well as butter and avocado.

*How do we apply this information?*

Getting adequate levels of vitamin E can be achieved by consuming several servings of nuts and seeds per week, as well as fish or avocado. Most people do not need to supplement with vitamin E to obtain an adequate amount from their diet.

### Vitamin K

Vitamin K is the name for a family of compounds known as the phylloquinones (vitamin K1) and menaquinones (vitamin K2). Vitamin K is involved in regulating blood homeostasis by controlling clotting. It also plays critical roles in bone formation and remodelling as well as working synergistically with vitamin D. Vitamin K has some interesting properties in that vitamin K1 can be obtained in the diet from plants, whereas vitamin K2 is the product of bacterial fermentation and must either be made by the gut bacteria or consumed in supplemental form, come from some animal foods, or be derived from bacteria [(](https://paperpile.com/c/cZDv7y/4L7jf)Elder, Haytowitz, Howe, Peterson, & Booth, n.d.).

Deficiencies in vitamin K lead to bleeding disorders where people cannot stop bleeding. Additionally, vitamin K deficiency can lead to osteoporosis, which can be improved by restoring vitamin K levels (Villa, Diaz, Pizziolo, & Martino, 2017).

*Where is it found in foods?*

Vitamin K is primarily found in dark, leafy greens, such as kale, collard and mustard greens, swiss chard, mustard parsley, romaine, green-leaf lettuce, & Brussels sprouts.

*How do we apply this information?*

Vitamin K is often overlooked in peoples' diets and there should be a concerted effort to focus on vitamin K intake. This can be accomplished by consuming dark, leafy greens several times a week and/or considering supplementation.

Fat-soluble vitamins differ substantially from water-soluble vitamins in that they are stored in bodily tissue and must be consumed with dietary fat to ensure proper absorption (Figure: Fat-Soluble Vitamins). Also, unlike water-soluble vitamins, deficiencies in these vitamins appear to be more common, especially vitamin D. Because these vitamins can be stored in tissues, vitamin toxicity from high intakes is also possible and diets that are high in fat-soluble, vitamin-rich foods should be monitored. When talking to clients about their nutrition, careful attention should be given to ensuring adequate levels of fat-soluble vitamin intake through the variety of foods suggested in this chapter.

This can be achieved by doing the following:

* Consuming fatty fish at least once a week
* Consuming several servings of vitamin-rich nuts and seeds (two to three) per day
* Consuming several servings of fortified dairy products (two to three) per day

Supplementation with any vitamins and minerals should be considered if advised by a registered dietitian nutritionist who may have access to a client’s lab work and can best assess their diet. A Nutrition Coach can support the recommendations to best assist the client.

### Common food sources of vitamins

Micronutrients are core components of all the foods that we consume. They give many foods their taste and colour and should not be viewed much differently than macronutrients as they co-occur. When helping support a client with their nutrition, it is important to consider both the quantity and quality of the diet. When supporting an RDN who may have created this diet for the client, the key is to understand how best to support the client in their quest to make better food choices.

The B-complex vitamins, folate, and vitamin C are found in a wide range of food sources. Vitamins B1, B2, B3, B5, B7, B12, and folate are all found in fortified grain products such as cereals, breads, and pastas. Vitamin B2 (riboflavin) is also found in milk and most organ meats (e.g., liver and kidney) while vitamin B3 (niacin) is found in beef, fish, and poultry. Vitamin B5 (pantothenic acid) is found in beef, poultry, organ meats, and eggs, as well as oatmeal and potatoes. Folate can also be found in leafy, green vegetables while biotin is found in small quantities in some fruits and beef and in moderate amounts in liver. Vitamin C is found primarily in fruits, specifically citrus fruits; however, it can also be found in dark, leafy greens, cruciferous vegetables, and tomatoes.

Fat-soluble vitamins are found in similar food sources as the water-soluble vitamins. Vitamin A is found in dark, leafy greens and dark-coloured fruits, in high quantities in fish and liver, and in moderate quantities in milk products (e.g., milk and yogurt). Vitamin D is found in fatty fish (e.g., salmon, herring, and sardines), fish oils (e.g., cod liver oil), fortified cereal products, and fortified milk products. Vitamin E is in nuts and seeds (e.g., almonds, nuts, and sunflower seeds) and their cold-pressed oils, fruits and vegetables, and beef. Vitamin K is primarily in dark, leafy greens and some plant oils.

Food for Thought

When considering the major food sources of both water- and fat-soluble vitamins, it is abundantly clear that a diet rich in fruits; dark,-green, leafy vegetables; animal meats; and dairy will allow people to reach their micronutrient needs. Enriched and fortified grains and cereals are used to help offset diets that are missing in these food groups.