

## **Vitamins and Minerals: Micronutrients an Overview**

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Vitamins and minerals are chemical compounds necessary for homeostasis and metabolism, and are essential micronutrients required in the human body in varying amounts. There are 13 vitamins, organic substances that fall into two groups; water-soluble and fat-soluble vitamins. The fat-soluble vitamins are A, D, E and K and the water-soluble vitamins include the B complex vitamins and vitamin C. There are 8 B vitamins, including, B1, B2, B3, B5, B6, B7, B9 and B12. <sup>1</sup>

Minerals are inorganic micronutrients, and are divided into two main categories; major minerals and trace minerals. Major minerals are required in the body in greater amounts than trace minerals. Major minerals include calcium, phosphorus, potassium, sodium, chlorine, magnesium, and sulphur. Trace minerals include iron, iodine, fluoride, zinc, manganese, chromium, cobalt, molybdenum, copper, and selenium.<sup>3</sup>

Vitamins and minerals are called micronutrients because unlike macronutrients (proteins, fats and carbohydrates), they are required in only very small amounts in the body. However, the absence of vitamins and minerals in the body, can contribute to various illnesses. Although vitamins and minerals are both micronutrients, they differ in basic ways. Vitamins are organic substances that can be broken down by heat, air, or acid, while minerals are inorganic and maintain their chemical structure.<sup>2</sup>

Vitamins and minerals are required in small amounts for normal growth, development and on-going wellbeing. They are found naturally in the diet; however, food supplements may be used to augment dietary intakes of vitamins and minerals and are specifically recommended at life stages, e.g. folic acid for women of childbearing age, and vitamin D in infancy.<sup>5</sup>

Most vitamins can be provided solely in the diet. Requirements for some vitamins can be partly met through direct or indirect synthesis in the body, e.g. vitamin D can be formed in the skin on exposure to UVB radiation, niacin can be synthesised from the amino acid tryptophan, and vitamin K can be produced by bacterial fermentation in the gut. However, as biological synthesis of these nutrients is limited for various reasons, dietary intake remains essential to meet physiological requirements. <sup>5</sup>

Excess of some vitamins and minerals can have detrimental effects on health, therefore, EU legislation provides for the setting of maximum safe levels of vitamins and minerals in food supplements by the European Commission. However, these are yet to be established. Currently, maximum levels of vitamins and minerals in food supplements are at the discretion of the manufacturer, provided the supplement is not unsafe. In the absence of official EU maximum levels, the Food Safety Authority of Ireland (FSAI) evaluates the safety of vitamins and minerals in food supplements in Ireland to protect consumer health and to provide

guidance to the food industry. When consumed according to manufacturer's instructions, the daily amount of a micronutrient in a food supplement as labelled, added to the usual daily intake from food sources (from foods including fortified foods, excluding supplements) of the highest consumers (95th percentile), should not exceed the tolerable upper intake level (UL) for the population groups for whom the food supplement is intended. <sup>5</sup>

### **Water Soluble Vitamins: B complex and Vitamin C.**

There are nine water-soluble vitamins, the B complex vitamins (thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, biotin, folate, and cobalamin) and vitamin C. Water-soluble vitamins dissolve in water upon entering the body. They are not stored in the body, and excess amounts are excreted in the urine. Regular intake is required to avoid deficiency due to the transient nature of water-soluble vitamins. <sup>6</sup>

**Vitamin B1 (Thiamine):** Thiamine, or vitamin B1, acts as a coenzyme in carbohydrate and branched-chain amino acid metabolism. It helps the body, break down and release energy from foods, and keeps the nervous system healthy. Thiamine is found in food sources such as whole grains breads, legumes, nuts, fortified breakfast cereal and liver. The RDA of thiamine for adults aged 19- 64 is 0.8mg/day for women and 1 mg/day for men. <sup>3,4</sup>

**Vitamin B2 (Riboflavin):** Riboflavin, or vitamin B2, acts as a coenzyme in redox reactions. Riboflavin is present in food sources such as enriched and whole grains, milk and dairy products, leafy vegetables, and beef. The RDA of riboflavin for adults aged 19- 64 is 1.1 mg/day for women, and 1.3 mg/day for men. <sup>3,4</sup>

**Vitamin B3 (Niacin):** Niacin, or vitamin B3, acts as a coenzyme to dehydrogenase enzymes in the transfer of the hydride ion, and is an essential component of the electron carriers NAD and NADP. Niacin provides the release energy from foods, and helps keep the nervous system and skin healthy. It is present in enriched and whole grains and high protein foods such as meat, milk, and eggs. The RDA of niacin for adults aged 19- 64 is 13.2 mg/day for women, and 16.5 mg/day for men. <sup>3,4</sup>

**Vitamin B5 (Pantothenic Acid):** Pantothenic acid, or vitamin B5, has several functions such as helping the body release energy from foods. It acts as a key component of coenzyme A and phosphopantetheine, which are crucial for fatty acid metabolism. Pantothenic acid is found widespread in foods including, all vegetables, wholegrain foods and meats. There is no listed RDA in Ireland for pantothenic acid. <sup>3,4</sup>

**Vitamin B6 (Pyridoxine):** Vitamin B6, or pyridoxine, acts as a coenzyme for amino acid, glycogen, and sphingoid base metabolism. Vitamin B6 is found widespread in food groups. The RDA for adults aged 19-64 is 1.4mg/day for men, and 1.2mg/day for women. <sup>3,4</sup>

**Vitamin B7 (Biotin):** Biotin, or vitamin B7, acts as a coenzyme in carboxylation reactions dependent on bicarbonate. It is needed in very small amounts to help the body make fatty acids. Biotin is found

widespread in foods, especially egg yolks, soybeans, and whole grains. There is no RDA for biotin, however, taking too much may be harmful. 0.9 mg or less daily in supplement form is unlikely to cause any harm. <sup>3,4</sup>

**Vitamin B9 (Folate):** Folate, or vitamin B9, acts as a coenzyme in single-carbon transfers in nucleic acid and amino acid metabolism. It is found in enriched and fortified grains, green leafy vegetables, and legumes. Folate helps the body form healthy red blood cells. The RDA of folate for adults is 200 mcg/day. The manmade form of folate is folic acid. The recommendation for pregnant women or women trying to conceive is 400 mcg/day of folic acid from supplements until 12 weeks pregnant, to decrease the risk of neural tube defects in the unborn baby. Women at risk of a pregnancy affected by a neural tube defect are advised to take 5mg of folic acid daily until 12 weeks pregnant. <sup>3,4</sup>

**Vitamin B12 (Cobalamin):** Vitamin B12, or cobalamin, acts as coenzymes for the crucial methyl transfer reaction in converting homocysteine to methionine and the isomerization reaction that occurs in the conversion of L-methylmalonyl-CoA to succinyl-CoA. Vitamin B12 is only present in animal products because it is a product of bacteria synthesis. Many foods are also fortified with synthetic vitamin B12. The RDA of vitamin B12 for adults aged 19-64 is 1.5 mcg/day. A lack of vitamin B12 can lead to vitamin B12 deficiency anaemia. <sup>3,4</sup>

**Vitamin C (Ascorbic Acid):** Vitamin C, or ascorbic acid, is an essential water-soluble vitamin that acts as a reducing agent in enzymatic reactions and non-enzymatically as a soluble antioxidant. It helps protect cells, keeping them healthy, and is important for healthy skin, blood vessels, bones and cartilage, and promotes wound healing. Vitamin C is found primarily in fruits and vegetables, and also in some foods of animal origin such as liver and kidneys. The RDA of vitamin C for adults aged 19-64 is 40mgs. When deficiency occurs, it can result in scurvy which can present with swollen and bleeding gums, loss of teeth, poor wound healing, and poor tissue growth. <sup>3,4,6</sup>

### **Fat Soluble vitamins (A, D, E and K)**

The body absorbs fat-soluble vitamins into newly forming micelles in the small intestine. Micelles are lipid clusters that contain hydrophobic groups internally and hydrophilic groups externally. This process relies on the secretion of bile and pancreatic enzymes. After absorption into enterocytes, fat-soluble vitamins become packaged into chylomicrons, which then get secreted into the lymphatic system before entering the bloodstream. Chylomicrons are metabolised by lipoprotein lipase, which causes the release of fat-soluble vitamins into tissues for use and storage. <sup>7</sup>

Unlike water soluble vitamins, fat soluble vitamins are stored in the body. While the body needs fat soluble vitamins every day to work properly, foods containing them do not need to be consumed daily. If the body does not require fat soluble vitamins for immediate use, it stores them in the liver and fatty tissues for future use. However, too much fat-soluble vitamins

accumulated in the body, can be harmful and fat-soluble vitamins consumed in excess, pose a greater risk of causing toxicity than water-soluble vitamins. <sup>5</sup>

**Vitamin A (Retinol):** Vitamin A is a generic descriptor for compounds that exhibit the biological activity of retinol and provitamin A carotenoids. Retinol is an unsaturated 20-carbon cyclic alcohol. Provitamin A carotenoids exhibit a 40-carbon basal structure with cyclic end groups and a conjugated system of double bonds. <sup>3</sup> Vitamin A, its analogues and its metabolites, function in vision, cell differentiation, embryogenesis, the immune response, reproduction and growth. Carotenoids also have a variety of different actions, including possible antioxidant activity, immune-enhancement, inhibition of mutagenesis and transformation, reduced risk of age-related macular degeneration and cataracts, decreased risks of some cancers, and decreased risk of cardiovascular events. Good sources of vitamin A include, cheese, eggs, oily fish, fortified low fat spreads, milk, yogurt, liver and liver products. The body can convert beta-carotene into Vitamin A. The main food sources of beta-carotene are, yellow, red and green leafy vegetables, such as spinach, carrots, sweet potatoes, red peppers, and any yellow fruit such as apricots, mango and papaya. <sup>4</sup> RDA of vitamin A for adults aged 19-64 are 600 ug for women, and 700 ug for men. Vitamin A deficiency is common in the developing world but is rare in developed countries. Severe deficiency causes night blindness and xerophthalmia, Bitot's Spots, xerosis conjunctiva and keratomalacia. <sup>5</sup>

**Vitamin D (Cholecalciferol):** Vitamin D helps regulate the amount of calcium and phosphate in the body, which helps keep bones, teeth and muscles healthy. Vitamin D is found primarily in two forms, D2 and D3. The body produces vitamin D3 (cholecalciferol) naturally from direct sunlight on the skin, hence the name the "sunshine vitamin.". However, there are very few rich natural food sources of vitamin D2 (ergocalciferol), and the main dietary sources are oily fish, cod liver oil, egg yolk and fortified foods. Studies have shown that adults in Ireland have low vitamin D levels. A lack of vitamin D can lead to bone deformities such as rickets in children and osteomalacia in adults. <sup>4</sup> Vitamin D is measurable in the serum in two forms, 25-hydroxyvitamin D and 1,25-dihydroxy vitamin D. 25-hydroxyvitamin D is the principal circulating form (levels in ng/ml). It has a half-life of 2 weeks, and is the best measure of vitamin-D status. Testing is indicated in populations at high risk for fractures, including those with osteoporosis, osteopenia, and the elderly. <sup>7</sup>

Infants, from birth to 1 year of age, who are being breastfed should be given a daily supplement containing 5 micrograms ( $\mu\text{g}$ ) of vitamin D. This should be provided by a supplement containing vitamin D exclusively. Infants, from birth to 1 year of age who are fed infant formula, should not be given a daily vitamin D supplement if they are having more than 300ml of infant formula a day. This is because infant formula is fortified with vitamin D and other nutrients. <sup>5, 7</sup> Children aged 1-4 years require 4-5  $\mu\text{g}$  of vitamin D as a supplement between October and March. It is difficult for people to get enough vitamin D from sunlight and food alone, and a supplement of 10  $\mu\text{g}$  is recommended for adults and children over 4

years of age during the autumn and winter months (October-March).<sup>8</sup> Taking more than 100 µg of vitamin D a day can be harmful for adults, the elderly and children aged 11-17. Children aged 1-10 years should not have more than 50 µg of vitamin D daily and infants under 12 months should not have more than 25 µg daily.<sup>8</sup>

Vitamin-D toxicity, although rare, can occur in individuals taking large doses of vitamin-D supplements with a heavy intake of fortified foods. Most symptoms of hypervitaminosis D stem from hypercalcemia caused by excessive calcium absorption in the duodenum and distal convoluted tubule. Clinical manifestations include gastrointestinal issues such as decreased appetite, diarrhoea, nausea, vomiting, and constipation. Hypercalcemia can result in polyuria, polydipsia, pruritus, and the development of kidney stones. Bone, muscle, and joint pain are also common manifestations.<sup>7</sup>

**Vitamin E (Tocopherol):** Vitamin E encompasses eight lipophilic compounds that include four tocopherols and four tocotrienols, each of which has a designation as  $\alpha$ -,  $\beta$ -,  $\gamma$ -, and  $\delta$ -. Each of these compounds contains a chromanol ring and a lipophilic tail. Tocotrienols differ from tocopherols with their unsaturated side chains.  $\alpha$ -tocopherol is the only form of vitamin E that is known to reverse deficiency symptoms.<sup>3</sup> Vitamin E helps strengthen the immune system and maintain healthy skin and eyes. Good sources of vitamin E include plant oils, nuts and seeds and wheatgerm. The RDA is 4mg/ day for men and 3mgs/day for women.<sup>9</sup>

**Vitamin K (Phylloquinone; Menaquinone):** Vitamin K occurs naturally in two main forms: K1 (phylloquinone), and K2 (menaquinone), which has many different forms. Vitamin K also occurs in the synthetic form of vitamin K3 (menadione), which contains only the 2-methyl-1, 4-naphthoquinone nucleus common to all forms of vitamin K. The natural forms differ by the number of isoprenoid units in their isoprenoid side chains.<sup>3</sup> Vitamin K is needed in the body for blood clotting and wound healing. It is present in green leafy vegetables, cabbage, and cauliflower, and lesser quantities are found in fish, meat, and some fruits. Adults need approximately 1 µg of vitamin K for each kg of their body weight.<sup>10</sup> Vitamin K is stored predominantly in the liver in the form of menaquinone and is excreted in the urine and faeces.<sup>3</sup>

## **Minerals: Major and Trace Minerals**

**Major Minerals:** Major minerals required in the body include calcium, phosphorus, potassium, sodium, chlorine, magnesium, and sulphur.

**Calcium:** Calcium is important for strong bones and teeth, muscle contraction and blood clotting. Sources of calcium in the diet include milk, cheese and dairy products, green leafy vegetables, sardines, and foods fortified with calcium such as bread.<sup>11</sup> The intestine, kidney, bone, and parathyroid gland work together to tightly regulate calcium balance in the body. Most of the calcium is absorbed in the small intestine via paracellular diffusion. The remainder of calcium is absorbed transcellularly through the calcium channel TRPV6 when luminal

calcium levels are low. 99% of the calcium in the body is found in the bones and teeth, while the remainder is found in soft tissues and plasma, both intracellularly and extracellularly. Most calcium is reabsorbed in the kidney, but the remainder is excreted in urine and faeces.<sup>3</sup> Adults aged 19-64 need 700mg of calcium/day.<sup>11</sup>

**Phosphorus:** Phosphorus is a mineral that helps build strong bones and teeth and release energy from food. Good dietary sources include red meat, dairy products, fish, poultry bread, brown rice and oats. Adults require 550 mg of phosphorus per day.<sup>12</sup> Throughout the body, phosphorus is distributed 85% in the skeleton, 0.4% in the teeth, 14% in the soft tissue, 0.3% in the blood, and 0.3% in the extravascular fluid. The kidney plays a role in phosphorus homeostasis through the reabsorption of inorganic phosphate from the glomerular filtrate in the proximal convoluted tubule. Approximately 75- 85% of phosphorus is reabsorbed per day, and the remainder is excreted in the urine. <sup>3</sup>

**Potassium:** Potassium helps regulate fluid balance, muscle contractions and nerve signals and supports normal blood pressure. Good dietary sources of potassium include, bananas, vegetables such as broccoli and brussels sprouts, beans and pulses, nuts and seeds, fish, beef and chicken. Adults aged 19-64 need 3,500mg of potassium daily.<sup>13</sup> Most of the dietary potassium is absorbed in the small intestine via passive transport. The kidney maintains potassium homeostasis. About 90% of the potassium consumed is excreted in the urine, with the remaining small amount excreted in stool and sweat. Most of the potassium content in the body is found in the intracellular space of the skeletal muscle.<sup>3</sup>

**Sodium Chloride:** Sodium and chloride minerals are needed in small amounts to maintain the fluid balance in the body. Chloride also helps the body digest foods. Adults should consume no more than 6g of sodium daily.<sup>14</sup> Sodium and water balance are closely linked and maintained by the kidneys. Half of the sodium in the body is found in extracellular fluid, while around 10% is found in intracellular fluid. The remaining 40% of sodium is found in the skeleton. Small losses of sodium can occur through urine, faeces, and sweat.<sup>3</sup> The kidneys regulate chloride concentration. Around 99% of chloride is reabsorbed in the proximal tubule of the kidneys both paracellularly and transcellularly via the Cl<sup>-</sup>/HCO<sub>3</sub><sup>-</sup> exchanger. The remainder of chloride can be excreted in urine, faeces, or sweat.<sup>3</sup>

**Magnesium:** Magnesium is necessary in the body to convert food into energy, and is important for proper functioning of the parathyroid glands. Good sources of dietary magnesium include spinach, nuts and wholemeal bread. The RDA for adults aged 19-64 is 300mgs/day for men, and 270mgs/day for women.<sup>15</sup> About 70% of serum magnesium is available for glomerular filtration, and 96% of the filtered magnesium is reabsorbed in the kidneys through several mechanisms in the proximal tubule, ascending limb, and distal tubule. The remaining magnesium is excreted in the urine. 99% of magnesium in the body is stored intracellularly in bone, muscle, and soft tissues, while 1% of magnesium in the body is found in extracellular fluid.<sup>3</sup>

**Sulphur:** Sulphur is necessary for insulin production, and enables the cells of the body to use glucose as energy. Keratin, a sulphur containing protein is a key structural component of the outer layer of human skin. Sulphur is involved in certain amino acid production in the body, and in the synthesis of collagen. There is no RDA for sulphur in the diet. Sources include, dairy, eggs, beef, poultry, seafood, onions, garlic, turnips, kale, and broccoli.<sup>3</sup>

**Trace minerals:** Trace minerals include iron, iodine, fluoride, zinc, manganese, chromium, cobalt, molybdenum, copper, and selenium.

**Iron:** Iron is important for production of red blood cells, which carry oxygen around the body. A lack of iron can lead to iron deficiency anaemia. Good sources of iron include liver (avoid during pregnancy), red meat, beans, nuts, dried fruit and fortified breakfast cereals. The RDA of iron is 8.7mg for men over 18, 14.8mg/day for women aged 19-50, and 8.7mg/day for women over 50. Very high doses of iron can be fatal, particularly in children. Iron supplements should always be kept out of reach of children.<sup>16</sup>

**Iodine:** Iodine is an essential component of the thyroid hormones thyroxine (T4) and triiodothyronine (T3). Thyroid hormones regulate many important biochemical reactions, including protein synthesis and enzymatic activity, and are critical determinants of metabolic activity. They are also required for proper skeletal and central nervous system development in the foetus and infants.<sup>18</sup> Good dietary sources of iodine include sea fish and shell fish. It can also be found in plant-based foods such as cereals and grains, but levels depend on the amount of iodine in the soil where the plants are grown. Adults require 140 ug of iodine daily. If following a strict vegetarian or vegan diet, supplements may be required.<sup>17</sup>

**Fluoride:** Sodium fluoride protects teeth from acid demineralisation, and strengthens tooth enamel while preventing tooth decay by bacteria. Excess fluoride exposure during tooth mineralisation, especially in children 1-3 years old, may cause fluorosis. In humans, the only clear effect of inadequate fluoride intake is an increased risk of dental caries for individuals of all ages.<sup>3</sup> While fluoride is not essential for human growth and development, excess intake can cause fluorosis affecting teeth and bone density. Since 2007, the level of fluoride in public water supplies in the Republic of Ireland has been set at between 0.6 and 0.8 mg/L.<sup>5</sup>

**Zinc:** Zinc helps blood to clot, is essential for taste and smell, and bolsters the immune response. It is involved in the production of new cells and enzymes, processes carbohydrates, fat and protein in food, and promotes wound healing. Good sources of zinc include, meat shellfish, dairy products such as cheese, bread and wheatgerm. The RDA of zinc for adults aged 19-64 is 9.5mg/day for men, and 7mg for women.<sup>19</sup>

**Manganese:** Manganese helps activate certain enzymes in the body and carry out chemical reactions. Good dietary sources of manganese are bread, nuts, wholegrain cereals and green vegetables such as peas. For most people taking 4mg of manganese supplements is unlikely to cause any harm. Older people may be more sensitive to manganese, however, taking 0.5mg or less of manganese supplements is unlikely to cause harm. Taking high doses of manganese

for a long time may cause muscle pain and nerve damage, and may also cause symptoms of fatigue and depression.<sup>20</sup>

**Chromium:** Chromium helps form a compound in the body that enhances the effects of insulin and lower glucose levels. Good sources of chromium include, meat, nuts and cereal grains. Approximately 25ug of chromium per day is required for adults.<sup>21</sup>

**Cobalt:** Cobalt helps absorb and process vitamin B12. In addition, cobalt helps treat illnesses such as anaemia and certain infectious diseases. Cobalt also aids in repair of myelin, which surrounds and protects nerve cells, and helps in the formation of haemoglobin. Good food sources include, fish, nuts, green leafy vegetables such as broccoli and spinach, and cereals, such as oats. Getting enough vitamin B12 in the diet provides enough cobalt in the body. Adults need approximately 0.0015mg (1.5 ug) of vitamin B12 a day.<sup>22</sup>

**Molybdenum:** Molybdenum helps make and activate enzymes that produce genetic material. Molybdenum is found in a wide variety of foods, and good sources includes potatoes and carrots. There is no recommended daily intake for molybdenum. The average intake via diet is usually around 76 mcg per day for women and 109 mcg for men. If taken in supplement form, a maximum of around 45mcg per day is suggested. The upper limit, where it may cause harm, is estimated to be 2000mcg per day.<sup>23, 24</sup>

**Copper:** Copper produces red and white blood cells and helps form several enzymes, one of which assists with iron metabolism and the creation of haemoglobin which carries oxygen in the blood. It is also important for infant growth, brain development, the immune system and strong bones. Good dietary sources include, nuts, shellfish and offal. Adults aged 19-64 require 1.2g of copper per day. Taken in high doses over long periods of time, copper can cause liver and kidney damage.<sup>25</sup>

**Selenium:** Selenium is an essential component of various enzymes and proteins called selenoproteins, that help to make DNA and protect against cell damage and infections. These proteins are also involved in reproduction and the metabolism of thyroid hormones. Most selenium in the body is stored in muscle tissue, although the thyroid gland holds the highest concentration of selenium due to various selenoproteins that assist with thyroid function.<sup>26</sup> Good sources of dietary selenium include brazil nuts, fish, meat and eggs. The RDA for adults aged 19-64 is 75ug/day for men, and 60ug/ day for women. If taking supplements, it is important not to take too much, as it can be harmful to the body. Too much selenium in the body can lead to a metallic taste, GI symptoms, and cause selenosis, the mildest form of which causes hair loss and brittle and discoloured nails.<sup>27</sup>

Micronutrients are needed by the body in very small amounts. However, their impact on the body's health is very important, and deficiency in any of them can cause severe and even life-threatening conditions. Micronutrient deficiencies can cause visible and dangerous health conditions, but can also lead to less clinically notable reductions in energy level, mental clarity

and overall capacity. Many of these deficiencies are preventable through nutrition education and consumption of a healthy balanced diet containing diverse foods, as well as food fortification and supplementation, where needed.

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