Nutrition Lecture: Trace Essential Minerals

Objectives

1. Know why minerals are essential to health (Recommendations)
2. Be able to distinguish between the bulk essential and trace minerals that are important to human health
3. Understand the major function(s) of each trace mineral
4. Discern between the major symptoms of deficiency and excess of the trace minerals

Resources

1. Merck & Co., Inc.

“The mineral depletion of foods available to us as a nation (1940-2002)--a review of the 6th Edition of McCance and Widdowson”. Thomas D

Abstract: Over the past 60 years there have been fundamental changes in the quality and quantity of food available to us as a nation. The character, growing method, preparation, source and ultimate presentation of basic staples have changed significantly to the extent that trace elements and micronutrient contents have been severely depleted. This trend, established in a review of the 5th Edition of McCance & Widdowson's The Composition of Foods, is still apparent in this review of the 6th edition of the same work. Concurrently there has been a precipitous change towards convenience and pre-prepared foods containing saturated fats, highly processed meats and refined carbohydrates, often devoid of vital micronutrients yet packed with a cocktail of chemical additives including colourings, flavourings and preservatives. It is proposed that these changes are significant contributors to rising levels of diet-induced ill health. Ongoing research clearly demonstrates a significant relationship between deficiencies in micronutrients and physical and mental ill health.
**Recommendations**

1. Minerals are necessary for the normal functioning of the body's cells. The body needs large quantities of sodium, potassium, calcium, magnesium, chloride, and phosphate. These minerals are called macrominerals. The body needs small quantities of copper, fluoride, iodine, iron, selenium, and zinc. These minerals are called trace minerals.

2. Minerals are an essential part of a healthy diet. The recommended dietary allowance (RDA)—the amount most healthy people need each day to remain healthy—has been determined for most minerals. People who have a disorder may need more or less than this amount.

3. Consuming too little or too much of certain minerals can cause a nutritional disorder. People who eat a balanced diet containing a variety of foods are unlikely to develop a nutritional disorder or a major mineral deficiency, except iron or iodine deficiency.

4. People who follow restrictive diets may not consume enough of a particular mineral. For example, vegetarians, including those who eat eggs and dairy products, are at risk of iron deficiency.

5. Some minerals—especially the macrominerals—are important as electrolytes. The body uses electrolytes to help regulate nerve and muscle function and acid-base balance. Also, electrolytes help the body maintain normal volume in its different fluid-containing areas (compartments). Electrolytes are dissolved in three main compartments: the fluid within the cells, the fluid in the space surrounding the cells, and the blood.

6. To function normally, the body must keep the concentration of electrolytes in its compartments within very narrow limits. The body maintains the concentration of electrolytes in each compartment by moving electrolytes into or out of the cells. The kidneys filter the electrolytes in the blood and excrete any excess in the urine to maintain a balance between daily intake and output.

7. If the balance of electrolytes is disturbed, disorders can develop. An electrolyte imbalance can occur when a person becomes dehydrated; uses certain drugs; has certain heart, kidney, or liver disorders; or is given intravenous fluids or feedings in inappropriate amounts.

8. To detect nutritional disorders or an electrolyte imbalance, doctors measure the levels of minerals in a sample of blood or urine.

### Important Minerals for Human Health

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Good Sources</th>
<th>Main Functions</th>
<th>Recommended Dietary Allowance for adults</th>
<th>Safe Upper Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>Milk and milk products, meat, fish, eggs, cereal products, beans</td>
<td>Required for the formation of bone and teeth, for blood clotting, for normal muscle function, and for</td>
<td>1,000 milligrams 1,200 milligrams for people older than 50</td>
<td>2,500 milligrams</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Element</th>
<th>Sources</th>
<th>Functions</th>
<th>Upper Adult Allowance (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride</td>
<td>Salt, beef, pork, sardines, cheese, green olives, corn bread, potato chips, sauerkraut, and processed or canned foods</td>
<td>Involved in electrolyte balance</td>
<td>1,000</td>
</tr>
<tr>
<td>Copper</td>
<td>Organ meats, shellfish (especially oysters), chocolate, mushrooms, nuts, dried legumes, and whole-grain cereals</td>
<td>Used to form enzymes that are necessary for energy production, for antioxidation (protection against cell damage due to reactive by-products of normal cell activity called free radicals), and for formation of the hormone epinephrine, red blood cells, bone, and connective tissue</td>
<td>900</td>
</tr>
<tr>
<td>Fluoride</td>
<td>Saltwater fish, tea, coffee, and fluoridated water</td>
<td>Required for the formation of bone and teeth</td>
<td>3 milligrams for women, 4 milligrams for men</td>
</tr>
<tr>
<td>Iodine</td>
<td>Seafood, iodized salt, dairy products, and drinking water (in amounts that vary by the iodine)</td>
<td>Required for the formation of thyroid hormones</td>
<td>150 micrograms</td>
</tr>
<tr>
<td>Mineral</td>
<td>Content of local soil</td>
<td>Description</td>
<td>Requirements</td>
</tr>
<tr>
<td>---------</td>
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</tr>
<tr>
<td>Iron</td>
<td>As heme iron: Meats, poultry, fish, kidneys, and liver As nonheme iron: Soybean flour, beans, molasses, spinach, clams, dried fruit, and fortified cereals</td>
<td>Required for the formation of many enzymes in the body Is an important component of muscle cells and of hemoglobin (which enables red blood cells to carry oxygen and deliver it to the body’s tissues)</td>
<td>8 milligrams 18 milligrams for women younger than 50 (premenopause) 27 milligrams for pregnant women 9 milligrams for breastfeeding women</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Leafy green vegetables, nuts, cereal grains, and seafood</td>
<td>Required for the formation of bone and teeth, for normal nerve and muscle function, and for the activation of enzymes</td>
<td>320 milligrams for women 420 milligrams for men</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Milk, cheese, meat, poultry, fish, cereals, nuts, and legumes</td>
<td>Required for the formation of bone and teeth and for energy production Used to form nucleic acids, including DNA (deoxyribonucleic acid)</td>
<td>700 milligrams 4,000 milligrams</td>
</tr>
<tr>
<td>Potassium</td>
<td>Whole and skim milk, bananas, tomatoes, oranges, melons, potatoes, sweet potatoes, prunes,</td>
<td>Required for normal nerve and muscle function Involved in electrolyte balance</td>
<td>3.5 grams</td>
</tr>
<tr>
<td><strong>Selenium</strong></td>
<td>Meats, seafood, and cereals (depending on the selenium content of soil where grains were grown)</td>
<td>Acts as an antioxidant, with vitamin E, protecting cells against damage by free radicals, which are reactive by-products of normal cell activity. Required for thyroid gland function.</td>
<td>55 micrograms</td>
</tr>
<tr>
<td><strong>Sodium</strong></td>
<td>Salt, beef, pork, sardines, cheese, green olives, corn bread, potato chips, sauerkraut, and processed or canned foods</td>
<td>Required for normal nerve and muscle function. Involved in electrolyte balance.</td>
<td>1,000 milligrams</td>
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<tr>
<td><strong>Zinc</strong></td>
<td>Organ meats such as liver, eggs, and seafood</td>
<td>Used to form many enzymes and insulin. Required for healthy skin, healing of...</td>
<td>15 milligrams</td>
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</table>
wounds, and
growth

Specific Trace Minerals
A. Copper

Most of the copper in the body is located in the liver, bones, and muscle, but traces of copper occur in all tissues of the body. The liver excretes excess copper into the bile for elimination from the body. Copper is a component of many enzymes. Some of these enzymes are necessary for energy production or for the formation of the hormone epinephrine (Trade Name ADRENALIN), red blood cells, bone, or connective tissue (which binds other tissues and organs together). Other enzymes act as antioxidants. They help protect cells against damage by free radicals, which are reactive by-products of normal cell activity.

Copper Deficiency: Copper deficiency is rare among healthy people. It occurs most commonly among infants who are premature, who are recovering from severe undernutrition, or who have persistent diarrhea. A severe disorder that impairs absorption of nutrients (such as celiac disease, Crohn's disease, cystic fibrosis, or tropical sprue) may cause this deficiency. A high intake of zinc or iron can decrease the absorption of copper.

-Symptoms of copper deficiency include fatigue, bleeding under the skin, damage to blood vessels, and an enlarged heart. Anemia is common, and the number of white blood cells is decreased.

-The diagnosis of copper deficiency is based on symptoms and on blood tests that detect low levels of copper and ceruloplasmin (a protein that contains copper). Copper deficiency is treated with a copper supplement.

Copper Excess: Excess consumption of copper is rare. Any copper not bound to a protein is toxic. Acidic food or beverages in prolonged contact with copper vessels, tubing, or valves can be contaminated with small amounts of unbound copper. Consuming even relatively small amounts of unbound copper may cause nausea, vomiting, and diarrhea. Large amounts can damage the kidneys, inhibit urine production, and cause anemia due to the rupture of red blood cells (hemolysis) and even death.

-The diagnosis is made by measuring copper and ceruloplasmin levels in the blood or urine. Treatment involves use of drugs that bind with copper.

Other- Wilson's Disease: When Copper Accumulates

**In Wilson's disease, a rare hereditary disorder, the liver does not excrete excess copper into the bile as it normally does. As a result, copper accumulates in and damages the liver. The damaged liver releases copper directly into the bloodstream, and copper is carried to other organs, such as the brain and eyes, where it also accumulates.

-In the cornea of the eyes, the accumulated copper produces gold or greenish rings.

B. Fluoride
In the body, most fluoride occurs in bones and teeth. Fluoride is necessary for the formation and health of bones and teeth.

**Fluoride Deficiency:** Fluoride deficiency can lead to tooth decay and possibly osteoporosis. Consuming enough fluoride can prevent tooth decay and may strengthen bones. The addition of fluoride (fluoridation) to drinking water that is low in fluoride or the use of fluoride supplements significantly reduces the risk of tooth decay.

**Fluoride Excess:** People who live in areas where the drinking water has a naturally high fluoride level may consume too much fluoride—a condition called fluorosis. Fluoride accumulates in the teeth, particularly permanent teeth. Chalky white, irregular patches appear on the surface of the tooth enamel, causing the \textit{enamel to appear mottled}. The teeth may also become pitted. These defects appear to affect appearance only and may even make the enamel more resistant to cavities. Fluoride also accumulates in bones. Rarely, consuming too much fluoride for a long time results in dense but weak bones, \textit{abnormal bone growths} (spurs) on the spine, and crippling due to \textit{calcium accumulation} (calcification) in ligaments.

-The diagnosis is based on symptoms. Treatment involves reducing fluoride consumption. For example, people who live in areas with fluoridated water should not drink fluoridated water or take fluoride supplements. Children should always be instructed not to swallow fluoridated toothpaste.

**C. Iodine**

Most of the iodine in the body occurs in the thyroid gland. Iodine in the thyroid gland is necessary for the formation of \textit{thyroid hormones}.

**Iodine Deficiency:** Iodine deficiency is rare, because in most countries, iodine (as iodide) is added to commercial table salt.

-When iodine is deficient, the thyroid gland enlarges, forming a \textit{goiter}, as it attempts to capture more iodine for the production of thyroid hormones. Iodine deficiency causes the same symptoms as an \textit{underactive thyroid gland} (hypothyroidism). In adults, such symptoms include puffy skin, a hoarse voice, impaired mental function, dry and scaly skin, sparse and coarse hair, and weight gain. If a pregnant woman has this deficiency, the growth and brain development of the fetus may be abnormal. Unless the baby is treated soon after birth, \textit{mental retardation with short stature} (cretinism) develops. If a nuclear radiation accident occurs, iodine deficiency increases the risk of thyroid cancer in children because the deficient thyroid gland collects the radioactive iodine.

-The diagnosis of iodine deficiency is based on blood tests indicating low levels of iodine and thyroid hormones or a high level of \textit{thyroid-stimulating hormone} (TSH) or on the presence of a \textit{goiter (only in adults)}. Treatment consists of iodine supplements. Infants may also require supplements of thyroid hormone, sometimes throughout life.

**Iodine Excess:** Excess consumption of iodine is uncommon. It usually results from taking iodine supplements to treat a prolonged iodine deficiency. Sometimes people who live near the sea consume too much iodine because they eat a lot of seafood and drink water that is high in iodine. Iodine excess may cause the thyroid gland to become overactive and produce excess thyroid hormones (a disorder called \textit{hyperthyroidism}). As a result, the thyroid gland enlarges, forming a goiter.
-The diagnosis is based on symptoms and on high levels of iodine and thyroid hormones and a low level of TSH in the blood. Treatment involves using salt that is not fortified with iodine and reducing consumption of foods that contain iodine.

D. Iron

Much of the iron in the body occurs in hemoglobin. Hemoglobin is the component of red blood cells that enables them to carry oxygen and deliver it to the body's tissues. Iron is an important component of hemoglobin and muscle cells. Iron is also necessary for the formation of many enzymes in the body.

**The body recycles iron:** When red blood cells die, the iron in them is returned to the bone marrow to be used again in new red blood cells. A small amount of iron is lost each day, mainly in cells shed from the lining of the intestine. This amount is usually replaced by the 1 to 2 milligrams of iron absorbed from food each day.

**Food contains two types of iron:** Heme iron (found in animal products) and nonheme iron (found in most foods and in iron supplements). Nonheme iron accounts for more than 85% of iron in the average diet. However, less than 20% of nonheme iron that is consumed is absorbed into the body. Nonheme iron is absorbed better when it is consumed with animal protein and with vitamin C. Heme iron is absorbed much better than nonheme iron.

Iron Deficiency: Iron deficiency is the most common mineral deficiency in the world, causing anemia in men, women, and children.

-In adults, iron deficiency is most commonly caused by loss of blood. In premenopausal women, monthly menstrual bleeding may cause the deficiency. In men and postmenopausal women, iron deficiency usually indicates bleeding in the digestive tract—for example, from a bleeding ulcer or a polyp in the colon. The deficiency may also result from bleeding in other areas of the body, such as the kidneys.

-Iron deficiency may result from an inadequate diet, primarily in infants and small children, who need more iron because they are growing. Adolescent girls who do not eat meat are at risk of developing iron deficiency because they are growing and starting to menstruate. Pregnant women are also at risk of this deficiency, because the growing fetus requires large amounts of iron.

Symptoms: When iron reserves in the body are exhausted, anemia develops (Iron Deficiency Anemia). Anemia causes paleness, weakness, irritability, drowsiness, and fatigue. Concentration and learning ability may be impaired.

-In addition to anemia, iron deficiency may produce such symptoms as pica (a craving for nonfoods such as ice, dirt, or pure starch), spoon nails (a deformity in which the fingernails are thin and concave), and leg cramps at night.
Iron Excess: Excess iron can accumulate in the body. Causes include many blood transfusions and iron therapy given in excessive amounts or for too long. Another cause is hemochromatosis, a hereditary disorder. Excess iron consumed all at once causes vomiting, diarrhea, and damage to the intestine.

E. Selenium
Selenium occurs in all tissues. Selenium works with vitamin E as an antioxidant. It helps protect cells against damage by free radicals, which are reactive by-products of normal cell activity. Selenium is also necessary for the thyroid gland to function normally.

Selenium Deficiency: Selenium deficiency is rare, even in New Zealand and Finland, where selenium intake is much lower than in the United States and Canada. In China, where selenium intake is even lower, selenium deficiency occurs in association with Keshan disease, a viral disease that affects mainly children and young women. Keshan disease damages the heart, resulting in cardiomyopathy.

- In selenium deficiency, antioxidants are lacking in the heart and muscles. As a result, cardiomyopathy and muscle weakness may occur.
- Doctors suspect selenium deficiency on the basis of the person's circumstances and symptoms. Treatment with a selenium supplement may result in a complete recovery.

Selenium Excess: Taking more than 1 milligram of a nonprescription selenium supplement each day can have harmful effects. Symptoms include nausea and vomiting, loss of hair and nails, a skin rash, and nerve damage. The diagnosis is based on symptoms, particularly rapid hair loss. Treatment involves reducing selenium consumption.

F. Zinc
Zinc is widely distributed in the body. It is a component of more than 100 enzymes, including those involved in the formation of RNA (ribonucleic acid) and DNA (deoxyribonucleic acid). The level of zinc in the body depends on the amount of zinc consumed in the diet. Zinc is necessary for healthy skin, healing of wounds, and growth. Much of the zinc consumed in the diet is not absorbed.

Zinc Deficiency: Zinc deficiency is most likely to develop in people who eat little meat, liver, eggs, or seafood. Consuming phytic acid (found in grains) and large amounts of iron and calcium may reduce the absorption of zinc. Liver and pancreatic disorders, alcoholism, diabetes mellitus, and disorders that impair absorption can cause zinc deficiency. Taking diuretics can also cause zinc deficiency. People who must be fed intravenously for a long time may develop this deficiency. Acrodermatitis enteropathica, a rare hereditary disorder in which zinc cannot be absorbed, may result in zinc deficiency as well as diarrhea and rashes.

- Early symptoms include a loss of appetite and slowed growth in infants and children. Other symptoms include patchy hair loss, impaired taste and smell, inflammation of the skin (dermatitis), and night blindness. In men, sperm production may be reduced. The body's immune system and ability to heal wounds may be impaired. In acrodermatitis enteropathica, symptoms usually appear when an affected infant is weaned.
Doctors suspect zinc deficiency on the basis of the person's circumstances, symptoms, and response to zinc supplements.

**Zinc Excess:** Consumption of excess zinc is rare. It usually results from consuming acidic foods or beverages packaged in a zinc-coated (galvanized) container. Symptoms include a metallic taste in the mouth, nausea, vomiting, and diarrhea. Consumption of 1 gram or more (about 70 times the RDA) may be fatal. In certain industries, inhaling zinc oxide fumes can cause rapid breathing, sweating, and weakness—a disorder called metal fume fever. Consuming too much zinc for a long time can reduce the absorption of copper and impair the immune system.

Doctors suspect the diagnosis based on the person's circumstances and symptoms. Treatment involves reducing zinc consumption.