Nutrition Text
Chapter 13: The Trace Minerals
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Overview:

The trace minerals (also known as microminerals) are iron, zinc, iodine, selenium, copper, manganese, fluoride, chromium, and molybdenum, all minerals that are necessary for the maintenance of good health, but are needed in very small quantities – less than 5g. These vital minerals can be toxic if present in significantly higher levels.

Iron

Iron's Roles in the body

Iron has two ionic states, "ferrous" (+2 charge) in its reduced state, and "ferric" (+3 charge) when oxidized. The ability of iron to switch between these states allows it to serve as a cofactor to enzymes involved in oxidation-reduction (extremely widespread) reactions.

Iron is required for the production of amino acids, hormones, collagen and neurotransmitters, and participates in the electron transport chain.

In the body, iron is found mostly as ***hemoglobin and myoglobin*, and in both of these cases, the iron helps in ***oxygen exchange***.

Iron Absorption and Metabolism

Absorption: mucosal ferritin stores dietary iron in small intestinal mucosal cells, and releases it via mucosal transferrin and blood transferrin. Intestinal cells are shed every three days, and excess iron goes with them into fecal matter.

Heme and Nonheme Iron: Heme is from animal sources only, comprises 10% of average protein intake, and is absorbed at a rate of about 25%; non-heme is from both plants and animals, and about 17% of non-heme is absorbed.

Absorption-Enhancing Factors: ***MFP (meat, fish, poultry) factor, vitamin C***, Citric acid, lactic acid, HCl from the stomach, and sugars all increase nonheme iron absorption. Vitamin C contributes to this by converting insoluble ferric iron in foods to ferrous iron, which is soluble.

Absorption-Inhibiting Factors: ***Phytates***, fibers and oxalates found in vegetables, as well as calcium, phosphorous, EDTA and tannic acid all bind to nonheme iron, inhibiting its absorption.

Iron Transport and Storage: Blood transferrin carries iron to tissues. Bone marrow uses the most iron in the production of new blood cells. Excess iron is stored as ferritin, in the liver, bone marrow and spleen. If levels are especially high, the liver can convert ferritin into hemosiderin, which releases iron slower than does ferritin. Storing excess iron protects the body from its action as a free radical (Highlight 11 has more on free radicals).

Iron Recycling: When blood cells degrade (every four months), the iron is salvaged: the liver allows it to bond to blood transferrin, which transports it to the bone marrow, where it is again incorporated into red blood cells.

Iron Deficiency

It's the most common nutrient deficiency, with 1.2 billion deficient people, some of whom develop iron-deficiency anemia. Most at-risk groups are pregnant women, infants and young children, adolescent girls and women who are in their reproductive years. Basically anything that makes you bleed or grow can cause iron deficiency.

Assessment of Iron Deficiency:

1. Serum ferritin levels are the first measurable change, showing decreased iron stores.
2. The second stage of iron deficiency involves a decrease in transport iron – serum iron falls, and transferrin increases to compensate. Transferrin saturation (how much transferrin is bound to iron) measures the degree of deficiency.
3. Hemoglobin and Hemocrit (the volume of red blood cells) values decline in stage three, when the lack of iron limits hemoglobin production, causing erythrocyte protoporphyrin to accumulate.

Iron deficiency and anemia: If low iron stores result in a low hemoglobin concentration, causing red blood cells to be pale, microcytic, and unable to carry adequate oxygen. Resulting symptoms include fatigue upon exertion, weakness, headaches, apathy, pallor and lowered resistance to cold temperatures.

Iron deficiency and behavior: Pre-anemic symptoms of iron deficiency include impairment of energy metabolism and neurotransmitter synthesis, reduction in physical work capacity and mental productivity. These signs can be mistaken for behavioral problems in children.

Pica: When iron-deficient people have cravings for non-food substances such as ice, clay and paste. This is called "Geophagia" when referring to clay and "pagophagia" when referring to ice.

Iron Toxicity

This is rare because the healthy body absorbs less iron when stores are full. Occurrence is greater in men than in women.

Iron Overload: Hemochromatosis is when too much iron is being absorbed; this is usually genetic in origin (and hereditary iron overload is the most common genetic disorder in the United States). Iron overload can also be caused by transfusions and supplements. Symptoms of iron overload are similar to iron deficiency: apathy, lethargy and fatigue – so to differentiate, transferrin saturation and serum ferritin tests are needed.

Long term consequences include hemosiderosis (deposits of hemosiderin, an iron protein), tissue (especially liver) damage, and increased risks of diabetes, hepatic cancer, heart disease and arthritis.

There may be some association of high iron levels and an increased risk for heart disease and cancer, because of iron's ability to generate free radicals.

Iron Poisoning: Iron overdosing can cause constipation, vomiting, nausea, and diarrhea in adults, and additionally a rapid heartbeat, dizziness, a weak pulse, shock, confusion and death (from as little as 200 mg) in young children.

Iron Recommendations and Sources

Recommended Iron Intakes: Omnivorous men need 8 mg per day; omnivorous, fertile women need 18 mg per day; vegetarians need 1.8 times those amounts. 45 mg is considered an upper daily limit for adults.

Iron in Foods: Top sources of iron are clams, beef liver, parsley, lean beef, flour tortillas and pinto beans. Generally meats are high, grains and legumes are intermediate, vegetables are low and milk products are very low in iron.

Enriched breads often contain extra iron, but it is absorbed less than naturally occurring iron ("Enriched" bread means that it has added iron and some B vitamins).

To absorb the most nonheme iron from your diet, consume meats for MFP and vegetables for vitamin C.

Iron Contamination and Supplementation

Contamination Iron: Iron salts from iron cookware can be absorbed by food cooked in them. These salts count as dietary iron intake.

Iron supplements: Good sources are supplements with ferrous sulfate or iron chelate, and these are best taken between meals (i.e., on an empty stomach), and with liquid other than milk, tea or coffee, all of which limit absorption. Since supplemental iron is in its ferrous form, vitamin C is not necessary for its absorption.

Zinc

Zinc is required as a cofactor by over 100 enzymes.

Zinc's Roles in the Body

Zinc supports action of proteins, including metalloenzymes which are involved with metabolism. Zinc also stabilizes cell membranes, assists in immune function, growth, development, insulin processing, blood clotting, thyroid function, wound healing, sperm production, taste sensation, fetal development, vision, behavior and learning.

Zinc Absorption and Metabolism

Zinc Absorption: 15-40% of dietary zinc is absorbed, depending on internal levels and dietary factors (phytates and fiber both limit absorption of zinc because they bind to it). Zinc is absorbed into intestinal cells, which can use the zinc themselves or reserve it with metallothionein, which can hold zinc in either the intestine or the liver, and then release zinc into the blood for other uses.

Zinc Recycling: The pancreas incorporates zinc into digestive enzymes, which are released at mealtimes. This gives the intestine another chance to absorb the zinc, and is referred to as enteropancreatic circulation of zinc. Zinc losses occur in feces, urine, shed skin, hair, sweat, menstrual fluids and semen.

Zinc Transport: Albumin is the primary transporter of zinc, followed by transferrin – this is the same transferrin as for iron transport, so iron overload limits zinc transport, and vice-versa. Large doses of zinc can also cause problems with copper intake.

Zinc Deficiency

Zinc deficiency is rare in developed countries but can occur in pregnant women, the young, the elderly and the poor. In chronic cases, all of the systems mentioned in "Zinc's Roles" can be affected. There is a potential for dwarfism and arrested sexual maturation, effects which are partially reversible if zinc is returned to the diet.

Zinc Toxicity

The recommended range is 8 mg per day for women and 11 mg per day for men, with an upper limit of 40 mg; more than this can lead to vomiting, diarrhea, headaches, loss of appetite, impaired immunity, low HDL, exhaustion and interference with copper metabolism, which leads to cardiac muscle degeneration.

Zinc Recommendations and Sources

Shellfish, meats, poultry, and liver are the best sources of zinc, followed by legumes and whole grains. Supplements are usually unnecessary in developed nations.

Iodine

Iodide's Roles in the Body: Iodide, the iodine ion, is an important part of thyroid hormones which regulate body temperature, metabolic rate, reproduction, growth, blood cell production, and nerve and muscle function.

Iodine Deficiency: The RDA is 150 micrograms per day.

The hypothalamus controls pituitary secretion of thyroid-stimulating hormone (TSH) which acts on the thyroid to make it produce thyroid hormone (TH), for which iodine is necessary. In the absence of iodine, TH levels are very low and TSH levels

increase substantially in a futile attempt to increase TH production. The thyroid gland can enlarge to trap as much iodine as possible, which can result in a large benign swelling called a goiter. Of the 200 million people who have goiters, 96% are iodine-deficient and 4% have consumed an excess of goitrogen, which is an antithyroid substance.

Children with iodine deficiencies perform poorly in school. Severe iodine deficiency during pregnancy can result in cretinism, an extreme and irreversible mental and physical retardation, which affects 6 million people worldwide.

Iodine Toxicity: Excessive iodine can enlarge the thyroid gland, and *in utero* overexposure to iodine can result in suffocation by goiter. The upper limit is 1100 micrograms per day.

Iodine Recommendations and Sources: The need for iodine is best met by consuming seafood, vegetables grown in iodine-rich soil, and iodized salt.

Selenium

Selenium Shares some chemical characteristics of sulfur, allowing it to substitute for sulfur in methionine, cysteine and cystine (Under oxidizing conditions, two cysteines can join together by a disulfide bond to form the amino acid cystine).

Selenium's Roles in the Body: Selenium works as part of the enzyme glutathione peroxidase, which works with vitamin E to prevent free-radical formation and propagation.

Selenium Deficiency: Selenium deficiency is associated with a heart disease known as Keshan, which is caused more directly by a virus and is found mainly in China. Selenium may also be protective against some forms of cancer.

Selenium Recommendations and Sources: RDA is 55-400 micrograms per day, which basically everyone gets without trying in the United States.

Selenium Toxicity: Too much selenium causes loss and brittleness of hair and nails, garlic breath odor, and nervous system abnormalities.

Copper

The body contains 100 mg of copper

Copper's Roles in the body: Copper is a constituent of enzymes with diverse metabolic roles, all of which involve the consumption of oxygen or oxygen radicals. Copper is therefore a key factor in hemoglobin synthesis. Copper is also needed in many metabolic reactions related to the release of energy.

Copper Deficiency and Toxicity: RDA is 900 micrograms – 10 mg per day. Copper deficiency is rare, but causes raised cholesterol and blood vessel damage. Menkes disease, a genetic disorder, intestinal cells absorb copper but cannot release it into circulation, causing a life-threatening deficiency.

Toxicity is unlikely to occur from excessive intake, but can happen from genetic disorders such as Wilson's disease, in which copper accumulates in the liver and brain, creating a life-threatening toxicity. Reducing copper intake, using chelating agents and taking zinc supplements are treatments for this disorder.

Copper Recommendations and Sources: Legumes, whole grains, nuts, shellfish and seeds are rich sources of copper. Over 50% of dietary copper is absorbed; elimination is through bile.

Manganese

The body contains 20 mg of manganese, mostly in the bones, liver, kidney and pancreas

Manganese's roles in the body: Manganese is a cofactor for many enzymes that facilitate carbohydrate, lipid and amino acid metabolism, and manganese-containing metalloenzymes also assist in bone formation and pyruvate conversion.

Manganese deficiency and toxicity: AI (based on average intake) for men is 2.3 mg/day and for women is 1.8 mg/day. Upper limit for adults is 11 mg/day. Deficiencies

are rare. Toxicity is more likely, and is possible due to long-term inhalation of large quantities of manganese, which can happen from occupational exposure (as in with miners). Symptoms of manganese toxicity are nervous system disorders, including changes in appearance and behavior.

Manganese Recommendations and Sources: Grain products are the main source of dietary manganese.

Fluoride

Fluoride's Roles in the Body: Calcium and phosphorous form hydroxyapatite crystals in the mineralization of bones and teeth. Fluoride replaces the hydroxyl portions of the crystals, forming fluorapatite, which strengthens bones and teeth.

Fluoride and Dental Caries: Dental Caries occur in 95% of the population of the United States, making it our most wide-spread health problem. Drinking water is usually the best source of fluoride – 65% of us drink fluoridated water. Bottled water does not generally have fluoride. The concentration of 1 part fluoride per 1 million parts water is ideal.

Fluoride toxicity: For men, AI is 3.8 mg/day and for women it is 3.1 mg/day. The upper limit is 10 mg/day. More can lead to fluorosis, which causes specks on teeth, pitting of the enamel, and sometimes permanent staining. This is why you're not supposed to swallow toothpaste.

Fluoride Recommendations and Sources: In addition to fluoridated water, good sources are fish and tea.

Chromium

Chromium's Roles in the Body: Chromium enhances insulin activity, helping to maintain glucose homeostasis. Chromium deficiency can lead to symptoms of diabetes. Chromium does not help in cases of actual diabetes.

Chromium Recommendations and Sources: The best sources are unrefined foods like liver, brewer's yeast and whole grains.

Molybdenum

Molybdenum works as part of several metalloenzymes. Dietary deficiencies are unknown due to the low levels needed. God sources are legumes, bread and grains, leafy green vegetables, milk and liver. AI for adults is between 45 micrograms and 2 mg/day. Toxicity is rare, but includes kidney damage and reproductive abnormalities in animal studies.

Other Trace Minerals

Nickel may be a cofactor; silicon and vanadium are involved in osteogenesis and chondrogenesis; cobalt is a key mineral in B12; boron may be important in neuronal activity. Trace element research continues.

Contaminant Minerals

Contaminant minerals such as lead, mercury and cadmium impair health. Lead poisoning is the most serious environmental threat to children. Lead displaces iron, calcium and zinc, preventing their normal actions. Given the range of important activities of these minerals, it is not surprising that lead poisoning has serious and widespread effects.

Highlight: Phytochemicals and functional foods

Phytochemicals are plant-derived (phyto means plant) and functional foods are those that contain physiologically active compounds which can provide health benefits beyond nutrition (also known as designer foods or nutraceuticals).

There is a table of some of the phytochemicals, their sourcse and actions on page 466. Please check it out for more specifics and examples.

The Phytochemicals
Phytochemicals can create taste, odor, color, heat, flavor, etc., in foods, and can also act as antioxidants, suppress diseases, and mimick hormones.

Defending Against Cancer: Phytoestrogens (found in soy, flax, whole grains, fruits and vegetables) weakly mimic or modulate estrogen, and slow the growth of breast and prostate cancers. Lycopene, which imparts red coloration to fruits like tomatoes, papaya and watermelon, also protects against esophageal, pulmonary, prostatic and gastric cancers.

Defending Against Heart Disease: Flavonoids, which are found in whole grains, legumes, soy, fruits and vegetables, herbs, spices, teas, chocolate, nuts, olive oil and red wine, are antioxidants that may help to protect LDL cholesterol from being oxidzed, and reduce platelet stickiness, demoting clotting. Favonoids have only been shown to be effective when consumed as part of foods, not as supplements. Carotenoids, such as lutein and lycopene, have also been found to be associated with decreased risk of heart disease. Phytoesterols found in soybeans and other vegetables inhibit cholesterol absorption in the body, lowering blood cholesterol levels. Phytoestrogens may also act as antioxidants and lower blood pressure.

Functional Foods
All whole foods can be seen as functional foods: cranberries protect against urinary tract infections, garlic can lower blood cholesterol, etc. Synthetic functional foods are also on the rise, from calcium-fortified orange juice to fungal-derived mycoprotein being made into meat substitute.

Foods as Pharmacy: Lactobacillus in yogurt are probiotics, meaning that they change the population of gastrointestinal microbes, improving defenses against disease in the GI tract. Margarine has been developed that is enhanced with a phytoesterol, and teas, snack-foods and other items are fortified with chemicals claiming all sorts of health benefits (promoting relaxation, providing energy, improving karma, etc.) – blurring the line between food and pharmaceutical, and giving food manufacturers an excuse to triple their prices.

Unanswered Questions: The author of this section is not convinced of the utility of these types of foods because they are often not proven effective, can sometimes cause people to eat foods that are otherwise unhealthy (i.e., when phytochemicals are added to fried food or chocolate), and can even be toxic because manufacturers don't necessarily have the scientific knowledge necessary to engineer their products in this way.

Future Foods
Food could be engineered to perfectly fit our bodies' needs, which might almost achieve what nature did without our interference.