NUTRIENTS: Minerals Part II

Introduction

In continuation with the first part, let us learn about microminerals in this unit. In earlier unit, you learnt about the definition and classification of minerals. You learnt about the functions, deficiency and excess of macrominerals and ultratrace minerals. This chapter describes functions, deficiency and toxicity for the microminerals.

A precise definition for the essential microminerals has not been established. The term *micro* when applied to microminerals can be defined as minerals that make up <0.01% of total body weight. An element is considered essential if a dietary deficiency of that element consistently results in a suboptimal biological function that is preventable or reversible by physiological amounts of the element. The abnormalities induced by deficiencies are always accompanied by specific biochemical changes.

Each essential micromineral is necessary for one or more functions in the body. Whenever the intake or body concentration is too low or too high, function is impaired and death can result. The body's content of the microminerals ranges from <1mg-~4g

Thorough study of this unit will be able to understand functions and deficiency/excess of the following microminerals

- ✓ Iron
- ✓ Zinc
- ✓ Copper
- ✓ Fluoride
- ✓ Manganese
- ✓ Chromium
- ✓ Iodine
- ✓ Molybdenum
- ✓ Selenium

1. Iron

The human body contains ~2-4g iron, or ~38mg iron/kg body weight (BW) for women and ~50mg iron/kg BW for men. Iron exists in a complex form in our body. It is present as

i. Iron porphyrin compounds-hemoglobin (65%) in RBC, myoglobin (10%) in muscle.
ii. Enzymes (1-5%)–peroxidases, succinase dehydrogenase and cytochrome oxidase.
iii. Transport and storage forms (20%): transferrin and ferritin.

The total amount of iron found in a person not only is related to BW but also is influenced by other physiological conditions, including age, gender, pregnancy, and state of growth.

a. Functions

The chief functions of iron in the body are :

1. Iron forms a part of the protein–haemoglobin which carries oxygen to different parts of the body.
2. It forms a part of the myoglobin in muscles which makes oxygen available for muscle contraction.
3. Iron is necessary for the utilization of energy as part of the cells metabolic machinery.
4. As part of enzymes iron catalyzes many important reactions in the body. Examples are
    i. Conversion of β-carotene to active form of Vitamin-A
    ii. Synthesis of carnitine, purines, collagen
    iii. Detoxification of drugs in the liver

b. Deficiency

Iron deficiency occurs most often due to inadequate iron intake. Iron intake is frequently inadequate in four population groups:

- Infants and young children (6 months to about 4 years), because of the low iron content of milk and other preferred foods, rapid growth rate, and insufficient body reserves of iron to meet needs beyond about 6 months
- adolescents in their early growth spurt, because of rapid growth and the needs of expanding red blood cell mass
- females during childbearing years, because of menstrual iron losses
- pregnant women, because of their expanding blood volume, the demands of fetus and placenta, and blood losses to be incurred in childbirth

In addition, many nonpregnant females during childbearing years fall short of the RDA for iron because of restricted energy intake and inadequate consumption of iron-rich foods.

Dietary iron deficiency leads to nutritional anaemia. Nutritional anaemia is defined as the condition that results from the inability of the erythropoetic tissue to maintain a normal haemoglobin concentration. Anaemia occurs when the haemoglobin level falls below 12gm/dl in adult man and woman. During pregnancy haemoglobin level below 11gm/dl is termed anaemia.

The major cause of anemia in India is because of Iron and folic acid deficiency.

Nutritional anemia is manifested as:

1. Reduced Haemoglobin level
2. Defects in the structure, function of the epithelial tissues
3. Paleness of skin and the inside of the lower eyelid is pale pink
4. Finger nails becoming thin and flat and eventually (spoon shaped nails) koilonychia develops.
5. Progressive untreated anaemia results in cardiovascular and respiratory changes leading to cardiac failure. The general symptoms include lassitude, fatigue, breathlessness on exertion, palpitations, dizziness, sleeplessness, dimmness of vision, and increased susceptibility to infection.

- Symptoms of iron deficiency, mostly demonstrated in children, include pallor, listlessness, behavioral disturbances, impaired performance in some cognitive tasks, some irreversible impairment of learning ability, and short attention span.

c. Excess

Accidental iron overload has been observed in young children following excessive ingestion of iron pills or vitamin/mineral pills. Other people susceptible to iron overload have a genetic disorder known as *hemochromatosis.* In most people with hemochromatosis iron absorption generally continues, despite high iron stores. The absorbed iron is progressively deposited within joints and tissues, especially the liver, heart, and pancreas, causing extensive organ damage and ultimately organ failure.

2. Zinc

The human body contains ~1.5-2.5g of zinc. Zinc is found in all organs and tissues and in body fluids. Largest stores of Zinc is present in the bones. Zinc forms a constituent of the blood. Zinc is an important element performing a range of function in the body as it is a cofactor for a number of enzymes.

a. Functions

Zinc functions in association with more than 300different enzymes. It participates in reactions involving either synthesis/degradation of major metabolites-carbohydrates, lipids, proteins-and nucleic acids. It plays important structural role in brain cells. Zinc is involved in the stabilization of protein and nucleic acid structure as well as in transport processes, immune function and expression of genetic information. It plays a major role in the synthesis of DNA and proteins, and a constituent of the hormone insulin. Zinc appears in the crystalline structure of bone, in bone enzymes. It is thought to be needed for adequate osteoblastic activity, formation of bone enzymes such as alkaline phosphatase and calcification.

b. Deficiency

Some population groups, especially the elderly and vegetarians, have been found to consume less than adequate amounts of zinc. Conditions associated with an increased need for intake include alcoholism, chronic illness, stress, trauma, surgery and malabsorption. Signs and symptoms of zinc deficiency are growth retardation, skeletal abnormalities, defective collagen synthesis or cross-linking, poor wound healing, dermatitis, delayed sexual maturation in children, hypogeusia (blunting of sense of taste), alopecia (hair loss), impaired immune function and impaired protein synthesis.

c. Excess

Excessive intake of zinc can cause toxicity. An acute toxicity with 1-2g zinc sulfate (225–450mg zinc) can produce a metallic taste, nausea, vomiting, epigastric pain, abdominal cramps and bloody diarrhea.

3. Copper

The adult body contains approximately about 80mg Copper. Concentrations of copper are highest in the liver, brain, heart and kidney. Muscle contains a low level of copper, but, because of its large mass, skeletal muscle contains almost 40% of all the copper in the body.

a. Functions

Copper is a component of many enzymes and symptoms of copper deficiency are attributable to enzyme failures. Copper in ceruloplasmin has a well-documented role in oxidizing iron before it is transported in the plasma. Lysyl oxidase, a copper-containing enzyme, is essential in the lysine-derived cross-linking of collagen and elastin. Copper has roles in mitochondrial energy production. As part of copper-containing enzyme such as superoxide dismutase, copper protects against oxidants and free radicals and promotes the synthesis of melanin and catecholamines

b. Deficiency

Clinical manifestations associated with copper deficiency. are hypochromic anemia, leukopenia, hypopigmentation or depigmentation of skin and hair, impaired immune function, bone abnormalities, cardiovascular and pulmonary dysfunction. The likelihood of copper deficiency increases in persons consuming excessive amounts of zinc (40mg/day) or antacids as well as in persons with conditions that promote increased loss of copper from the body, as occurs with nephrosis or gastrointestinal malabsorptive disorders such as celiac disease, tropical sprue, and inflammatory bowel diseases

c. Excess

Copper toxicity is fairly rare. A tolerable upper level for copper is set at 10mg per day. Copper intake of 64mg (250mg copper sulfate) has resulted in epigastric pain, nausea, vomiting, and diarrhea. Other symptoms of toxicity include hematuria, liver damage resulting in jaundice, and kidney damage resulting in oliguria or anuria.

Wilson’s disease, a genetic disorder characterized by copper toxicity, results from mutation(s) in the gene coding. In Wilson’s disease, copper accumulates in organs, resulting in disturbed function of organs, especially the liver, kidneys, and brain. Kayser-Fleischer (greenish gold) rings caused by copper deposition also are visible in the cornea.

4. Fluoride

Fluoride is found in natural element in nearly all drinking water and soil and in the human body in trace amounts. Fluoride is not considered an essential nutrient, but it is clearly recognized as important for the health of bones and teeth.

a. Functions

Fluoride is essential for tooth enamel. Fluoride incorporation into enamel produces more stable apatite crystals. Fluoride also acts as an antibacterial agent in the oral cavity, serving as an enzyme inhibitor.

b. Deficiency

Fluoride deficiency in test animals has been reported to result in curtailed growth, infertility and anemia. In humans, an optimal level of fluoride helps to reduce the incidence of dental caries and perhaps also to maintain the integrity of skeletal tissue.

c. Excess

Chronic toxicity of fluoride, called fluorosis, is characterized by changes in bone, kidney, nerve and muscle function. Dental fluorosis or mottling of teeth has been observed in children receiving 2-8mg fluoride/kg BW. Acute toxicity manifests as nausea, vomiting, diarrhea, acidosis, and cardiac arrhythmias.

3. Manganese

Although widely distributed in nature, manganese occurs in only trace amounts in animal tissues. The body of a healthy 70kg man is estimated to contain a total of 10-20mg of the metal.

a. Functions

Manganese is a component of many enzymes, including glutamine synthetase, pyruvate carboxylase and mitochondrial superoxide dismutase. Manganese is associated with the formation of connective and skeletal tissues, growth and reproduction, and carbohydrate and lipid metabolism

b. Deficiency

Manganese deficiency is associated with striking and diverse physiological malfunctions. Manganese deficiency generally does not develop in humans unless the mineral is deliberately eliminated from the diet. Symptoms and signs of deficiency included nausea, vomiting, dermatitis, decreased serum manganese, decreased fecal manganese excretion, increased serum calcium, phosphorus, and alkaline phosphatase, decreased growth of hair and nails; changes in hair and beard color; poor bone formation and skeletal defects; and altered carbohydrate and lipid metabolism.

c. Excess

Manganese toxicity has developed in miners as a result of absorption of manganese through the respiratory tract. The excess, which accumulates in the liver and central nervous system, produces Parkinson-like symptoms. Toxicity has also been reported in patients receiving TPN including manganese. Symptoms include headaches, dizziness.

6. Chromium

Chromium is found in air, water and soil. The chromium content of the human body is estimated at ~4-6 mg.

a. Functions

Chromium potentiates insulin action and as such influences carbohydrate, lipid and protein metabolism. Chromium may regulate the synthesis of a molecule that potentiates insulin action. Another possible role for chromium, similar to that of zinc, is in the regulation of gene expression.

b. Deficiency

Chromium deficiency is seen in people who received intravenous nutrition feeding (total parenteral nutrition) without chromium and without oral food intake. Signs and symptoms of deficiency included weight loss, peripheral neuropathy, elevated plasma glucose concentrations or impaired glucose use, and high plasma free fatty acid concentrations. Severe trauma and stress may increase the need for chromium. Chromium deficiency results in insulin resistance characterized by hyperinsulinemia, a risk factor for heart disease. Mild chromium deficiency also is a risk factor for metabolic syndrome. Metabolic syndrome increases the risk of heart disease.

c. Excess

Oral supplementation of upto about 1,000μg of chromium appears to be safe. Toxicity is associated with exposure to chromium absorbed through the skin, enter the body through inhalation, or be ingested. Inhalation of or direct contact with chromium may result in respiratory disease or in dermatitis and skin ulcerations. Liver damage may also occur. Ingesting chromium leads to severe acidosis, gastrointestinal hemorrhage, hepatic injury, renal failure and death.

4. 7. Iodine

Iodine is an essential micronutrient, which is required for the synthesis of thyroid hormone for optimal physical growth and development of humans. The healthy human body contains about 20mg of iodine, 70-80% of which is concentrated in the thyroid gland.

a. Functions

Iodine is stored in the thyroid gland, where it is used in the synthesis of triiodothyronine (Tr) and thyroxine (Tq). Uptake of iodide ions by the thyroid cells may be inhibited by goitrogens (substances that exist naturally in foods). Thyroid hormone is degraded in target cells and the liver, and the iodine is highly conserved under normal conditions.

b. Deficiency

Iodine deficiency in the diet causes enlargement of the thyroid gland called as “goitre”, as well as a wide spectrum of disorders, which are termed as iodine deficiency disorders (IDD). IDD includes abortion, stillbirths, low birth weight, cretinism, neonatal chemical hypothyroidism, psycho-motor defects, impaired coordination, mental retardation and hypothyroidism.

Goitre occurs in people staying in hilly regions where the iodine content of water and soil is comparatively less. Goitre can be treated by administration of iodine. If treatment is given in early stages goitre can be corrected.

Severe iodine deficiency in children leads to hypothyroidism resulting in retarded physical and mental growth. This condition is known as cretinism.

Goitrogens are substances present in foods which cause goitre. These substances react with iodine present in the food making it unavailable for absorption. Foods like cabbage, cauliflower, raddish contain goitrogens.

c. Excess

Excessive iodine intake is reportedly occurring because of poor monitoring and higher than necessary supplementation in several countries with supplementation programs. In addition, in some countries, excessive intake occurs from overconsumption of foods naturally high in iodine. Some signs of acute iodide toxicity include burning of the mouth, throat, and stomach; nausea; vomiting; diarrhea; and fever. A tolerable upper intake level for iodine has been set at 1,100µg/day.

5. 8. Molybdenum

The need for molybdenum was established in humans through the observation that a genetic deficiency of specific enzymes that require molybdenum as a cofactor resulted in severe pathology.

a. Functions

Xanthine oxidase, aldehyde oxidase, and sulfite oxidase, all enzymes that catalyze oxidation-reduction reactions, require a prosthetic group containing molybdenum.

b. Deficiency

Molybdenum deficiency has not been established in humans other than patients treated with TPN. Symptoms of molybdenum deficiency include mental changes and abnormalities of sulfur and purine metabolism

c. Excess

Molybdenum appears to be relatively nontoxic, with intake upto 1,500μg/day. However, symptoms such as gout have appeared in some people living in regions that contain high soil molybdenum levels and in those with occupational exposure to molybdenum.

9. Selenium

Selenium, a nonmetal, exists in several oxidation states. Selenium is important as it has antioxidant activity. The chemistry of selenium is similar to that of sulfur; consequently, selenium can often substitute for sulfur. The total body selenium content ranges from about 13-30mg.

a. Functions

Glutathione peroxidase is the only selenoprotein enzyme well studied for the biological role of selenium. Deiodinase isoenzymes that are involved in thyroid hormone metabolism are also selenium-containing proteins. Apart from its antioxidant protection against free radicals, selenium was found to be functional in detoxification.

b. Deficiency

Selenium deficiency has been associated with two childhood/adolescent endemic diseases, '*Keshan*' (cardiomyopathy) and '*KashinBeck*' (osteoarthritis). These diseases are found to be prevalent in certain areas where the intake of Selenium is very low, 7-11g/d. Poor intake of Selenium is associated with increased risk of cancer or heart disease.

c. Excess

Selenium toxicity, also called selenosis, has been observed both in miners and in people who consume excess selenium from supplements. Signs and symptoms of toxicity include nausea, vomiting, fatigue, diarrhea, hair and nail brittleness and loss, paresthesia, interference in sulfur metabolism and inhibition of protein synthesis. Acute poisoning selenium is lethal, with damage occurring to most organ systems. Daily intakes above 700µg/d or acute consumption of 1-7mg Selenium/kg/d results in toxicity in humans.

Conclusion

Micro when applied to minerals can be defined as minerals that make up <0.01% of total BW. The body's content of the microminerals ranges from <1mg-~4g. The microminerals are Iron, Zinc, Copper, Fluoride, Manganese, Chromium, Iodine, Molybdenum and Selenium. Microminerals functions in association with different enzymes, they participate in reactions involving synthesis, degradation of major metabolites-carbohydrates, lipids, proteins-and nucleic acids. They play important structural role and many biochemical functions. The abnormalities induced by deficiencies are always accompanied by specific biochemical changes. These biochemical changes can be prevented or cured when the deficiency is prevented or cured. Whenever the intake or body concentration is too low or too high, function is impaired and death can result.