Core Course 5: Food And Nutrition
UNIT III: NUTRIENTS: Minerals (Part- a)

Introduction

Until the middle of the nineteenth century, the importance of minerals was not known. It was observed that carbohydrate, fat, protein alone were incapable of promoting and sustaining growth. Hence scientists attempted to find out the "missing elements", namely minerals which are essential for growth and maintenance. Essential minerals which are inorganic substances are classified as macro and micronutrients based on the amount needed by humans per day. Macrominerals are those which are vital to health and that are required in the diet by more than 100mg/day. Microminerals or trace minerals are those required in the diet less than 20mg per day. The essential macrominerals are Calcium, Phosphorous, Magnesium, Sodium, Sulphur, Potassium and Chloride. Important microminerals of relevance in human nutrition are Iron, Zinc, Copper, Fluoride, Manganese, Chromium, Iodine, Molybdenum and Selenium. The ultratrace elements without established essentiality for humans, such as Cobalt, arsenic, boron, nickel, vanadium, and silicon, provide a negligible amount of weight. Minerals represent about 4-5% of body weight, or 2.8 to 3.5 kg in adult women and men, respectively. Approximately 50% of this weight is calcium, and another 25% is phosphorus, existing as phosphates. Almost 99% of the calcium and 70% of the phosphates are found in bones and teeth.

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

- ✓ Macrominerals – Calcium, Phosphorous, Magnesium, Sodium, Sulphur, Potassium and Chloride
- ✓ Ultratrace elements - Cobalt, arsenic, boron, nickel, vanadium, and silicon

1. Macrominerals

1.1. Calcium

Calcium (Ca) is an essential element required for several life processes, representing about 1.5-2% of total body weight, or between ~1,000g in a 60kg human.

Bones and teeth contain about 99% of the body's calcium. The other 1% is distributed in intra- and extracellular fluids.

a. Functions

1. Bone formation: The major mineral ions of the bone is Calcium. For proper calcification of bones, (deposition of minerals on the bone matrix) which occurs during the growing years, adequate supply of Ca is essential.
2. Tooth formation: Calcium is essential for the formation of dentin and enamel.
3. Physiological Process:
    i. Calcium is essential for the clotting of blood.
    ii. Calcium regulates the permeability of the capillary walls and ion transport across the cell membranes.
    iii. It is essential for the contraction of the heart and skeletal muscle.
    iv. Ca regulates the excitability of the nerve fibres.
    v. Ca acts as an activator for enzymes such as rennin and pancreatic lipase.

b. Deficiency

Calcium related health problems occur due to inadequate intake, improper absorption or utilization of calcium.

i. Osteoporosis:

Osteoporosis is a condition found primarily among middle aged and elderly woman, where the bone mass of the skeleton is diminished. It results due to the following reasons:

a. Prolonged dietary inadequacy
b. Poor absorption and utilization of calcium
c. Immobility
d. Decreased levels of oestrogen in post menopausal women.
e. Hyper parathyroidism
f. Vitamin–D deficiency

ii. Osteomalacia – is a condition in which the quality but not the quantity of bone is reduced.

iii.Tetany- Tetany occurs when Calcium in the blood drops below the critical level. There is a change in the stimulation of nerve cells resulting in increased excitability of the nerve and uncontrolled contraction of the muscle tissue.

c. Excess

Intake of calcium in amounts up to 2,500 mg daily appears to be safe for most people. The large intake of calcium resulted in hypercalcemia and deposition of calcium in soft tissues. Constipation also can occur when large amounts of calcium are ingested.

1.2. Phosphorus

Phosphorus is second only to calcium in abundance in the body. Approximately 560-850g are present in a 70kg human, representing about 0.8-1.2% of body weight. Of total body phosphorus, about 85% is in the skeleton, 1% is in the blood and body fluids, and the remaining 14% is associated with soft tissue such as muscle.

a. Functions

1. Bone formation: The major mineral ion of the bone is Phosphorous. For proper calcification of bones adequate supply of Phosphorous is essential.
2. Tooth formation: Phosphorous is essential for the formation of dentin and enamel.
3. Phosphorous is essential for the storage and release of adenosine triphosphate (ATP) molecules
4. Phosphates plays an important role as buffers to prevent changes in acidity of the body fluids.
5. Phoshpolipids are major components of cell membrane and intracellular organelles
6. In the DNA and RNA phosphate is an essential part of the nucleic acids

b. Deficiency

Phosphate deficiency is rare, but it could possibly develop in individuals who are taking drugs known as phosphate binders. Symptoms result primarily from decreased synthesis of ATP and other organic phosphate molecules. Neural, muscular, skeletal, hematologic, renal, and other abnormalities occur. Clinical phosphate depletion and hypophosphatemia can result from long-term administration of glucose or Total Parental Nutrition without sufficient phosphate, excessive use of phosphate-binding antacids, hyperparathyroidism or treatment of diabetic acidosis and it may develop in those who have alcoholism with or without decompensated liver disease.

c. Excess

Toxicity from phosphorus is rare. Problems have been reported only in infants when calcium:phosphorus ratios are altered significantly in favor of phosphorus. Phosphorus toxicity is characterized predominantly by hypocalcemia and tetany.

1.3. Magnesium

Like calcium, magnesium is closely associated with skeletal system. About 20-25g magnesium is present in adult human body and about 60-70% of it occurs in the bone, 25-30% in the muscle, 6-8% in soft tissues and 1% in the extracellular fluid.

a. Functions

1. The major function of magnesium is to stabilize the structure of ATP in ATP-dependent enzyme reactions
2. Magnesium is a cofactor for more than 300enzymes involved in the metabolism of food components.
3. Magnesium plays a role in neuromuscular transmission and activity
4. In a normal muscle contraction, calcium acts as a stimulator, and magnesium acts as a relaxant. Magnesium acts as a physiologic calcium-channel blocker.

b. Deficiency

Poor magnesium status may be related to cardiovascular disease, renal disease, diabetes mellitus, toxemia of pregnancy, hypertension, or postsurgical complications. Symptoms of abnormal neuromuscular function occur in magnesium depletion associated with malabsorption syndromes like inflammatory bowel disease or sprue,

primary idiopathic hypomagnesemia and severe protein energy malnutrition. In severe deficiency, the subjects suffer often from tetany and convulsions. Hypomagnesemia, hypocalcemia and hypokalemia are always associated with magnesium deficiency and are reversed by magnesium repletion. A syndrome of magnesium-dependent, vitamin D-resistant rickets is observed.

c. Excess

Although excess magnesium can inhibit bone calcification, magnesium excesses from dietary sources, including supplements, are very unlikely to result in toxicity. The only cases of toxicity that have been reported involve smelter workers who inhale.

1.4. Sodium

Approximately 30% of the ~105g of sodium in the body (70kg human) is located on the surface of bone crystals. The remainder of the body's sodium is in the extracellular fluid, primarily plasma, and in nerve and muscle tissue. Sodium constitutes about 93% of the cations in the body, making it by far the most abundant member of this family.

a. Functions

Within the body, sodium plays important roles in the maintenance of fluid balance, nerve transmission/impulse conduction, and muscle contraction. Sodium, potassium and chloride display the most movement across cell membranes to maintain osmotic pressure and thus fluid balance. Sodium's roles in nerve transmission and muscle contraction involve sodium as part of the Na+/K+-ATPase pump found in the plasma membrane of cells.

b. Deficiency

Dietary deficiencies of sodium do not normally occur because of the abundance of the mineral across a broad spectrum of foods. Excess sodium in the diet is said to contribute to hypertension in genetically prone individuals. Symptoms include muscle cramps, nausea, vomiting, dizziness, shock and coma.

c. Excess

Apart from its relationship to hypertension, at intakes of 590-680mmol daily, healthy individuals can develop fluid retention.

1.5. Potassium

Potassium is the major intracellular cation. About 95-98% of the body's potassium is found within body cells. Potassium constitutes up to ~0.35% of total body weight, or upto ~245 g in a 70 kg human

a. Functions

Potassium contributes to intracellular osmolality. Enzymes involved in glycosis and oxidative phosphorylation are potassium-dependent. It is involved in the maintenance of acid-base balance. Potassium is vaso-active, increasing blood flow and sustains metabolic needs of the tissue. Potassium supplements lower blood pressure. Potassium influences the contractility of smooth, skeletal and cardiac muscle and profoundly affects the excitability of nerve tissue.

b. Deficiency

Hyperkalemia is toxic, resulting in severe cardiac arrhythmias and even cardiac arrest. Similarly, hypokalemia does not occur by dietary deficiency because of the abundance of potassium in common foods. Hypokalemia is associated with cardiac arrhythmias, muscular weakness, nervous irritability, hypercalciuria, glucose intolerance, and mental disorientation and can result from profound fluid loss, such as the losses that occur with severe vomiting and diarrhea or with use of some diuretic medications. A moderate deficiency of potassium is associated with elevations in blood pressure, increased urinary calcium excretion, and abnormal bone turnover.

c. Excess

Hyperkalaemia can be fatal and result in cardiac arrest. Individuals with sub-clinical/clinical renal failure are at risk of hyperkalaemia.

1.6. Chloride

Chloride is the most abundant anion in the extracellular fluid, with approximately 88% of chloride found in extracellular fluid and just 12% intracellular. Its negative charge neutralizes the positive charge of the sodium ions with which it is

usually associated. In this respect, it is of great importance in maintaining electrolyte balance. Total body chloride content is about 0.15% of body weight, or about 105g in a 70kg human.

a. Functions

Chloride has important functions in addition to its role as a major electrolyte. The formation of gastric hydrochloric acid requires chloride. Chloride is released by white blood cells during phagocytosis to assist in the destruction of foreign substances.

b. Deficiency

Dietary deficiency of chloride does not occur under normal conditions. As is the case for the other electrolytes, deficiency arises chiefly through gastrointestinal tract disturbance such as severe diarrhea and vomiting.

1.7. Sulphur

Although sulfur has long been studied as a mineral, it functions almost entirely as a component of organic molecules. Sulfur exists in the body as a constituent of three amino acids-cystine, cysteine, and methionine-and of many other organic molecules.

a. Functions

Sulfhydryl groups of proteins participate in diverse cellular reactions. The sulfur of cysteine is involved photosynthesis, nitrogen fixation and oxidative phosphorylation. In the broadest sense, sulfur can be considered an antioxidant. Sulfur exists as a component of heparin, an anticoagulant found in liver and some other tissues and as chondroitin sulfate in bone and cartilage. Sulfur is also an essential component of three vitamins-thiamin, biotin and pantothenic acid.

b. Deficiency and Excess

Excess inorganic sulfur generated as a result of hepatic or renal metabolism is excreted in the urine as sulfates. These sulfates are thought to combine with calcium ions in the glomerular ultrafiltrate, thereby reducing the renal tubular resorption of calcium. Sulfur deficiency or toxicity is highly unlikely.

2. Ultratrace elements

2.1. Cobalt

Most of the cobalt in the body exists with vitamin B_{12} stores in the liver. Blood plasma contains approximately 1mcg of cobalt per 100.

a. Functions

The well-known essential role of cobalt is as a component of vitamin B_{12} (cobalamin) which is essential for the maturation of red blood cells and the normal function of all cells. In addition, methionine aminopeptidase, an enzyme involved in the regulation of translation is the only enzyme in humans known to have an established requirement of this trace element.

b. Deficiency

A cobalt deficiency develops only in relation to a vitamin B_{12} deficiency. Insufficient vitamin B_{12} causes a macrocytic anemia and genetic defect limiting vitamin B_{12} absorption results in pernicious anemia.

c. Excess

A high intake of inorganic cobalt in animal diets produces polycythemia (an overproduction of red blood cells), hyperplasia of bone marrow reticulocytosis, and increased blood volume.

2.2. Arsenic

More than any other ultratrace mineral, arsenic, which is colorless and odorless, conjures an image of toxicity as a poison rather than of nutritional essentiality.

a. Functions

Arsenic appears to be needed to form and use methyl groups, generated in methionine metabolism to S-adenosylmethionine (SAM). SAM is a major methyl donor in the body and functions in synthesizing a variety of compounds and in methylating compounds needed for DNA synthesis.

b. Deficiency

Arsenic deficiency impairs metabolism of methionine, resulting in decreased SAM concentrations. Arsenic-deficient rats fed, experienced growth deficits compared with arsenic-supplemented rats. Effects of arsenic deprivation in animals include curtailed growth, reduced conception rate, and increased neonatal mortality.

2.3. Boron

Boron, as boric acid and sodium borate (called borax), was used to preserve foods such as fish, meat, cream, butter, and margarine for over 50 years—that is, until about the 1920s, when it was considered dangerous for humans but deemed essential for plants.

a. Functions

Boron is thought to have several functions in the body, including roles in embryogenesis, bone development, cell membrane function and stability, metabolic regulation, and the immune response. Because of its anti-inflammatory effects, boron is purported to reduce the severity of rheumatoid arthritis

b. Deficiency and Excess

Boron deficiency has not been reported in humans, and no toxicity level has been established.

2.4. Nickel

Nickel is used industrially in various capacities, such as production of stainless steel and nickel-cadmium batteries. Nickel’s essentiality in human nutrition was first suggested in the 1930s.

a. Functions

A specific role of nickel in human and animal nutrition has not yet been defined, although roles for nickel in plants and microorganisms have been documented.

b. Deficiency

Signs of nickel deprivation continue to be described for some animal species. Among the more consistent signs are depressed growth, altered distribution of some minerals, changes in blood glucose, and impaired hematopoiesis.

c. Excess

Signs of toxicity in humans include nausea, vomiting, and shortness of breath; in animals, signs include lethargy, ataxia, irregular breathing, and hypothermia, among others, possibly including death.

2.5. Vanadium

Vanadium was first discovered in the early 1800s and named for a Swedish goddess, Vanadis. In solution, vanadium produces a range of colors, which accounts for its being named after the goddess. In its pentavalent state it is yellowish orange, whereas in its divalent state it is blue.

a. Functions

No specific biochemical function has been identified for vanadium. Vanadium mimics the action of insulin. Vanadium stimulates glucose uptake into cells, enhances glucose metabolism, and inhibits catecholamine induced lipolysis in adipose tissue. Vanadium also stimulates glycogen synthesis in the liver and inhibits gluconeogenesis. Vanadium also can substitute for other metals such as zinc, copper, and iron in metallo enzyme activity.

b. Deficiency

Vanadium deficiency has suggested that the element is associated with iodine metabolism, thyroid gland function, or both. Controlled depletion of vanadium has been reported to adversely affect growth rate, perinatal survival, physical appearance, hematocrit, and other manifestations in various animal species.

2.6. Silicon

Silicon occupies a unique position among the essential trace elements in that it is second only to oxygen in earthwide abundance.

a. Functions

The physiological role of silicon centers on normal formation, growth and development of bone, connective tissue, and cartilage. Silicon is thought to play both a metabolic and a structural role.

b. Deficiency

Silicon deficiency results in smaller, less flexible long bones and in skull deformation. Silicon deprivation in rats diminished bone collagen formation and increased collagen breakdown.

c. Excess

No tolerable upper intake level has been established for silicon. The major potential adverse effect reported is kidney stone. Toxicity of silicon also has been associated with diminished activities of several enzymes that prevent free radical damage. Silicosis occurs from inhaling dust high in silica; the condition is characterized by a progressive fibrosis of the lungs that leads to respiratory problems.

3. Conclusion:

Minerals are essential for growth and maintenance and they represent about 4-5% of body weight. Essential minerals which are inorganic substances are classified as macro and micronutrients. The essential macrominerals are Calcium, Phosphorous, Magnesium, Sodium, Sulphur, Potassium and Chloride. The ultratrace elements are Cobalt, arsenic, boron, nickel, vanadium and silicon. Calcium, phosphorus and magnesium are required for many roles such as bone formation, tooth formation and to perform many physiological process. Sodium, potassium and chloride are required for water, electrolyte and pH balances. Sulphur is component of some of the amino acids and vitamins. Deficiency symptoms of calcium causes rickets, osteomalacia, osteoporosis, and tetany, while phosphorus causes osteomalacia, rickets, and cardiac manifestations. Deficiency of phosphorus and magnesium develops symptoms related to neuromuscular, hematologic and muscular weakness. Weakness, anorexia, poor growth, loss of appetite, mental apathy, lethargy are some of the symptoms related to deficiencies of sodium, potassium and chloride. Deficiency of utltratrace elements is observed in animals with the symptoms of curtailed growth, altered bone mineralization, depressed growth and hematologic changes.

Table 1: Macrominerals: Functions, Body Content, Deficiency Symptoms, and Recommended Dietary Allowances (RDAs)

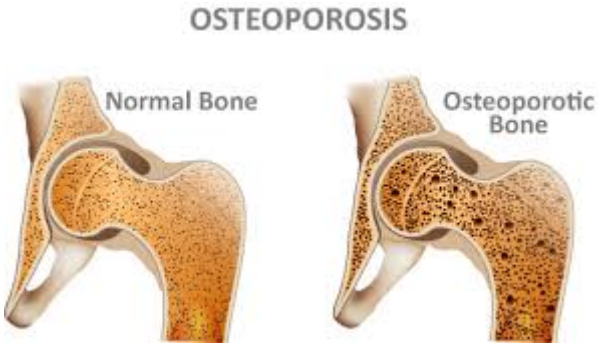
Mineral	**Selected Food Sources**	**RDA/AI**
Calcium	Milk, milk products, Bengalgram whole, gingely seeds, cuminseeds, poppy seeds, agathi, amaranth, drumstick leaves	600mg*
Phosphorus	Meat, poultry, fish, eggs, milk, milk products, nuts, legumes, grains, cereals	600mg*
Magnesium	Nuts, legumes, wholegrain cereals, leafy green vegetables	340mg males, 310mg females
Sodium	Table salt, meat, seafood, cheese, milk, bread, vegetables (abundant in most foods except fruits)	2092mg males, 1902mg females
Potassium	Avocado, banana, dried fruits, orange, peach, potatoes, dried beans, tomato, wheat bran, dairy products, eggs	3750mg males, 3225mg females
Chloride	Table salt, seafood, milk, meat, eggs	-
Sulfur	Protein foods—meat, poultry, fish, eggs, milk, cheese, legumes, Nuts	Not established

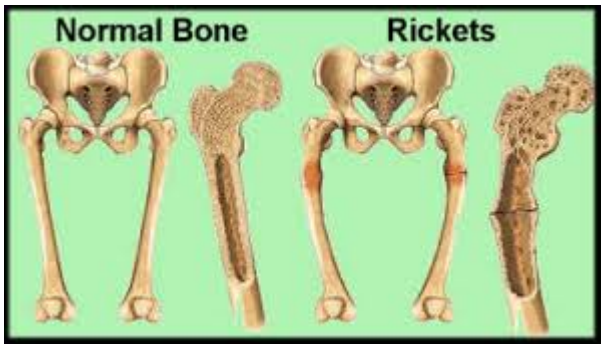
*Adequate intake: 19–50 years

Source: Gropper et al, (2009). In Advanced Nutrition and Human Metabolism

Table 2: Ultratrace Elements: Selected Functions, Deficiency Symptoms, and Food Sources

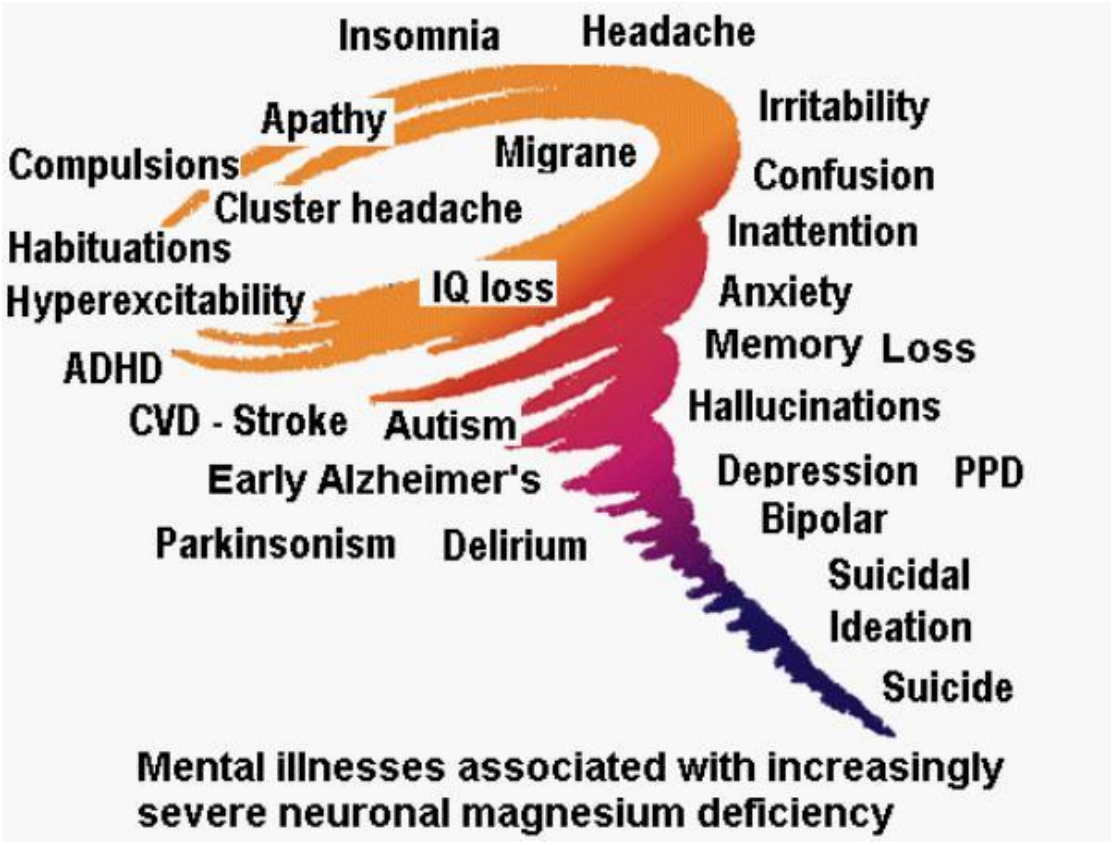
Mineral	**Selected Deficiency Symptoms in Animals**	**Food Sources**
Arsenic	Curtailed growth	Seafood
Boron	Altered bone mineral metabolism, depressed growth	Fruits, vegetables, legumes, nuts
Nickel	Depressed growth, impaired hematopoiesis	Nuts, legumes, grains, cacoa products
Silicon	Decreased collagen, long bone and skull abnormalities	Beer, unrefined grains, root vegetables
Vanadium	Reduced growth, hematologic changes, metabolism changes	Shellfish, spinach, parsley, mushrooms, whole grains





Tetany

Calcium Deficiency



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