**COURSE - BCH 208**

**TITLE - MINERAL METABOLISM**

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**MINERAL METABOLISM**

Minerals are inorganic elements, required for a variety of functions. The minerals required in human nutrition can be grouped into **macro minerals** and micro minerals **(trace elements)**

* The macro minerals are required in excess of 100 mg/day.
* The micro minerals or trace elements are required in amounts less than 100 mg/day.

**Minerals required in human nutrition**

Macro minerals Micro minerals or Trace elements

Sodium Chromium

Potassium Cobalt

Chlorine Copper

Calcium Fluoride

Phosphorus Iodine

Magnesium Iron

Sulfur Manganese

Molybdenum

Selenium

Zinc

METABOLISM OF SODIUM

Sodium is the major cation of extracellular fluids.

Dietary food sources

Table salt (NaCl), salty foods, animal foods, milk and some vegetables.

Recommended dietary allowance per day

• 1–5 gm

• 5 gm NaCl per day is recommended for adults without history of hypertension and 1 gm NaCl per day with history of hypertension.

Absorption and excretion

Sodium readily absorbed from the gut and is excreted from the body via urine. There is normally little loss of sodium occur through skin (sweat) and in the feces. Urinary excretion of sodium is regulated by aldosterone, which increases sodium reabsorption in kidney.

Metabolic functions

* It maintains the **osmotic pressure**and **water balance**.
* It is a constituent of **buffer**and involved in the maintenance of **acid-base balance**.
* It maintains **muscle**and nerve **irritability**at the proper level.
* Sodium is involved in **cell membrane permeability**.
* Sodium is required for intestinal absorption of glucose, galactose and amino acids.

**Plasma Sodium**

The plasma concentration of sodium is **135-145 mEq/L.** whereas blood cell (intracellular) contains only about **35 mEq/L**.

**Clinical Conditions Related to Plasma Sodium Level Alterations**

**Hypernatremia**

Hypernatremia is an increase in serum sodium concentration above the normal range of 135 – 145 mEq/L.

**Causes of hypernatremia**

* **Water depletion,** may arise from a decreased intake or excessive loss with normal sodium content, e.g. diabetes insipidus.
* **Water and sodium depletion*,*** if more water than sodium is lost, e.g. diabetes mellitus (osmotic diuresis), excessive sweating or diarrhea in children
* **Excessive sodium intake or retention**in the ECF due to excessive aldosterone secretion, e.g. **Cohn’s** **syndrome** and in **Cushing’s syndrome**.

**Symptoms of hypernatremia**

It is due to water loss, then the symptoms are therefore those of dehydration and if it is due to excess salt gain, leads to hypertension and edema.

**Hyponatremia**

It is a significant fall in serum sodium concentration below the normal range 135 to 145 mEq/L.

**Causes of hyponatremia**

* **Retention of water:** Retention of water dilutes the constituents of the extracellular space causing hyponatremia, e.g. in heart failure, liver disease, nephrotic syndrome, renal failure, syndrome of inappropriate ADH secretion (SIADH).
* **Loss of sodium:** Such losses may be from gastrointestinal tract, e.g. vomiting, diarrhea, or in urine. Urinary loss may be due to aldosterone deficiency (Addison’s disease).
* **Symptoms of hyponatremia**are constant thirst, muscle cramps, nausea, vomiting, abdominal cramps, weakness and lethargy.

**POTASSIUM**

Potassium is the main intracellular **cation.**About 98% of total body potassium is in cells (150–160 mEq/L), only 2% in the ECF (3.5–5 mEq/L).

**Dietary food sources**

Vegetables, fruits, whole grain, meat, milk, legumes and tender coconut water.

**Recommended dietary allowance per day**

2–5 gm.

**Absorption**

Potassium is absorbed readily by passive diffusion from gastrointestinal tract.

**Excretion**

* Potassium excretion occurs through three primary routes, the **gastrointestinal tract**, the ***skin*** and the ***urine***. Under normal conditions, loss of potassium through gastrointestinal tract and skin is very small. The major means of K+ excretion is by the kidney.
* When sodium is reabsorbed by distal tubule cations (e.g. K+ or H+) in the cell move into the lumen to balance the charge. **Thus during the sodium reabsorption there is an obligatory loss of potassium.**

**Serum potassium**

The concentration of potassium in serum is around **3.5**–**5 mEq/L*.*** Serum potassium concentration does not vary appreciably in response to water loss or retention.

**Metabolic functions**

* Potassium maintains the intracellular **osmotic pressure, water balance** and **acid-base balance**.
* It influences activity of cardiac and skeletal muscle.
* Several glycolytic enzymesneed potassium for their formation.
* Potassium is required for **transmission of nerve impulses**.
* **Nuclear activity** and **protein synthesis**are dependent on potassium.

**Clinical Conditions Related to Plasma Potassium Level Alterations**

**Hyperkalemia**

Hyperkalemia is a clinical condition associated with elevated plasma potassium above the normal range (3.5–5 mEq/L).

**Causes of hyperkalemia**

• **Renal failure:** The kidney may not be able to excrete a potassium load when GFR is very low.

**Mineralocorticoid deficiency:** For example, in Addison’s disease.

*•* **Cell damage:** For example, in trauma and malignancy.

**Symptoms of hyperkalemia**

First manifestation is cardiac arrest, changes in electrocardiogram, cardiac arrhythmia, muscle weakness which may be preceded by parasthesia (abnormal tingling sensation).

**Hypokalemia (low plasma concentration)**

**Causes of hypokalemia**

**Gastrointestinal losses:** Potassium may be lost from the intestine due to vomiting, diarrhea.

**Renal losses:** Due to renal disease, administration of diuretics.

**Symptoms of hypokalemia**

Muscular weakness, tachycardia, electrocardiographic (ECG) changes (flattering of ECG waves), lethargy and confusion.

**METABOLISM OF TRACE ELEMENTS (MICROMINERALS)**

**IODINE**

The adult human body contains about **50 mg** of iodine. The blood plasma contains 4–8 g of protein bound iodine (PBI) per 100 ml.

**Dietary food sources**

Seafood, drinking water, iodized table salt, onions, vegetables, etc.

**Recommended dietary allowance per day**

100–150 g for adults

**Functions**

The most important role of iodine in the body is in the synthesis of thyroid hormones, **triiodothyronine (T3)**

and **tetraiodothyronine (T4),** which influence a large number of metabolic functions.

**Absorption and excretion**

Iodine in the diet absorbed rapidly in the form of iodide from intestine. Normally, about 1/3rd of dietary iodide is taken up by the thyroid gland, a little by the mammary and salivary glands. The rest is excreted by the kidneys. Nearly 70–80% of iodine is excreted by the kidneys; small amounts are excreted through bile, skin and saliva. Milk of lactating women also contains some iodine.

**Deficiency manifestation**

Deficiency of iodine occurs in several regions of the world, where the iodine content of soil and therefore of plants is low. A deficiency of iodine in children leads to **cretinism** and in adult’s endemic **goiter.**

* ***Cretinism:*** Severe iodine deficiency in mothers leads to intrauterine or neonatal hypothyroidism results in cretinism in their children. Cretinism is characterized by mental retardation, slow body development, dwarfism and characteristic facial structure.
* ***Goiter:*** A goiter is an enlarged thyroid with decreased thyroid hormone production. An iodine deficiency in adults stimulates the proliferation of thyroid epithelial cells, resulting in enlargement of the thyroid gland. The thyroid gland collects iodine from the blood and uses it to make thyroid hormones. In iodine deficiency, the thyroid gland undergoes compensatory enlargement in order to extract iodine from blood more efficiently.

**IRON (Fe)**

A normal adult possesses **3–5 gm** of iron. This small amount is used again and again in the body. Iron is called a **one way substance,** because very little of it is excreted. Iron is not like vitamins or most other organic or even inorganic substances which are either inactivated or excreted in course of their physiological function.

**Dietary food sources**

The best sources of food iron include liver, meat, egg yolk, green leafy vegetables, whole grains and cereals.

There are two types of food iron:

* **Heme iron:** Iron associated with porphyrin is found in green leafy vegetables.
* **Non-heme iron:** Iron without porphyrin, and is found in meat, poultry and fish.

**Recommended dietary allowance per day**

* Adult men and post menopausal women: 10 mg
* Premenopausal women: 15–20 mg
* Pregnant women: 30–60 mg.

Women require greater amount than men due to the physiological loss during menstruation.

**Functions**

Iron is required for: Synthesis of heme compound like hemoglobin, myoglobin, cytochromes, catalase and peroxidase. Thus iron helps mainly in the **transport, storage** and **utilization of oxygen.**

• Synthesis of non-heme iron (NHI) compounds, e.g. iron-sulfur proteins of flavoproteins, succinate dehydrogenase

and NADH dehydrogenase.

**Absorption**

The normal intake of iron is about 10–20 mg/day. Normally, about 5–10% of dietary iron is absorbed. Most absorption occurs in the duodenum.

**Transport**

• The transfer of iron from the storage ferritin (Fe3+ form) to plasma involves reduction of Fe3+ to Fe2+ in the mucosal cell with the help of **ferroreductase**.

• Fe2+ then enters the plasma where it is reoxidized to Fe3+ by a copper protein, ***ceruloplasmin*** (ferroxidase).

• Fe3+ is then incorporated into **transferrin** by combining with **apotransferrin**.

• Apotransferrin is a specific iron binding protein. Each apotransferrin can bind with two Fe3+ ions is taken up by cells and either incorporated into heme or stored as ***ferritin*** or ***hemosiderin*.**

Storage of iron occurs in most cells but predominantly in cells of liver, spleen and bone marrow.

**Excretion**

• Iron is not excreted in the urine, but is lost from the body via the ***bile, feces*** and in ***menstrual blood***.

• Iron excreted in the feces is exogenous, i.e. dietary iron that has not been absorbed by the mucosal cells is excreted in the feces

**Factors affecting iron absorption**

• **State of iron stores in the body:** Absorption is increased in iron deficiency and decreased when there is iron overload.

• **Rate of erythropoiesis** (the process of red blood cell production). When rate of erythropoiesis is increased, absorption may be increased even though the iron stores are adequate or overloaded.

• **The contents of the diet:** Substances that form soluble complexes with iron, e.g. ascorbic acid (vitamin C) facilitates absorption. Substances that form insoluble complexes, e.g. phosphate, phytates and oxalates inhibit absorption.

• **Nature of gastrointestinal secretions and the chemical state of the iron:** Iron in the diet does notusually become available for absorption unlessreleased in free form during digestion. This dependspartly on gastric acid (HCl) production. Ferrous (Fe2+)is more readily absorbed than ferric form (Fe3+) andthe presence of HCl, helps to keep iron in the Fe2+form.

**Iron deficiency**

A deficiency of iron causes a reduction in the rate of hemoglobin synthesis and erythropoiesis, and can result in **iron deficiency anemia**. Iron deficiency anemia is the commonest of all single nutrient deficiencies. The main causes are:

• **Deficient intake:** Including reduced bioavailability of iron due to dietary fiber, phytates, oxalates, etc.

• **Impaired absorption:** For example, intestinal malabsorptive disease and abdominal surgery.

• **Excessive loss:** For example, menstrual blood loss in women and in men from gastrointestinal bleeding (in peptic ulcer, diverticulosis or malignancy). Iron deficiency causes low hemoglobin resulting in ***hypochromic microcytic anemia*** in which the size of the red blood cells are much smaller than normal and have much reduced hemoglobin content.

***Clinical features of anemia:*** Weakness, fatigue, dizziness and palpitation. Nonspecific symptoms are nausea, anorexia, constipation, and menstrual irregularities. Some individuals develop pica, a craving for unnatural articles of food such as clay or chalk.