Subject: Nutrition/2nd Semester (CC3T)/Ch-10

Paper: Nutritional Biophysics & Chemistry of Biomolecules

Topic Name: Minerals and Trace elements

(All Minerals in Brief)

Minerals and trace elements

Key points

- Minerals are inorganic substances required by the body in small amounts for a variety of different functions.
- Minerals are involved in the formation of bones and teeth; they are essential constituents of body fluids and tissues; they are components of enzyme systems and they are involved in normal nerve function.
- The body requires different amounts of each mineral; people have different requirements, according to their age, sex, physiological state (e.g. pregnancy) and sometimes their state of health.
- The Department of Health has published Dietary Reference Values (DRVs) for minerals for different groups of healthy people.

What are minerals?

Minerals are inorganic substances required by the body in small amounts for a variety of functions. These include the formation of bones and teeth; as essential constituents of body fluids and tissues; as components of enzyme systems and for normal nerve function.

Some minerals are needed in larger amounts than others, e.g. calcium, phosphorus, magnesium, sodium, potassium and chloride. Others are required in smaller quantities and are sometimes called trace minerals, e.g. iron, zinc, iodine, fluoride, selenium and copper. Despite being required in smaller amounts, trace minerals are no less important than other minerals.

Minerals are often absorbed more efficiently by the body if supplied in foods rather than as supplements. Also, a diet that is short in one mineral may well be low in others, and so the first step in dealing with this is to review and improve the diet as a whole. Eating a varied diet will help ensure an adequate supply of most minerals for healthy people.

Requirements and recommended dietary intakes

The body requires different amounts of each mineral because each mineral has a different set of functions. Requirements vary according to age, sex and physiological state (for example pregnancy). They may also be influenced by state of health. The Department of Health has published recommendations in the form of Dietary Reference Values (DRVs) for minerals for different groups of healthy people .

The bioavailability and absorption of minerals

The bioavailability of a mineral (i.e. how readily it can be absorbed and used by the body) may be influenced by a variety of factors. Bioavailability will depend upon the chemical form of the mineral, other substances present in the diet and (for nutrients such as iron) the individual person's needs as determined by how much of the nutrient is already stored in the body. This is because the body has sensitive mechanisms for preventing storage of nutrients that can be damaging in excess (as is the case with iron).

For example, the bioavailability of iron from plant sources (non-haem iron) is relatively poor compared with iron from meat (haem iron) but absorption is increased when vitamin C is consumed during the same meal because the vitamin C converts it to a more bioavailable chemical form.

Some dietary constituents reduce bioavailability. Phytate, for example, found in products made from wholegrain cereals (especially unleavened breads such as chapattis) can bind and hence reduce the absorption of calcium, iron and zinc. Iodine absorption may be hindered by nitrates. Similarly, oxalate present in spinach and rhubarb binds any calcium present, making it unavailable for absorption. Also an excess of one mineral may hinder the absorption of another by competing for the same transport systems in the gut, e.g. excess iron reduces zinc absorption. This generally only becomes a problem when zinc intakes are already marginal.

Unlike some vitamins, minerals are fairly stable in normal food processing and storage conditions.

Deficiencies and excess intakes

Iron deficiency anaemia is the most common nutritional deficiency in the world, often affecting women and young children, and is found in the UK population too. Iodine deficiency is also commonplace worldwide.

On the other hand, excess intakes of minerals are also sometimes of concern (for example sodium, one of several risk factors associated with high blood pressure). In general, excess intakes of a range of minerals have been reported to have varying effects, ranging from no effect (e.g. no adverse effects have been reported for excess iodine intakes up to 2mg iodine/day) to severe (e.g. excess fluoride can cause skeletal fluorosis).

Calcium

Calcium (Ca) is the most abundant mineral in the body and is essential for a number of vital functions. The body needs adequate dietary calcium (alongside vitamin D and several other nutrients such as vitamin K) to develop and maintain healthy bones and teeth. Calcium also plays a vital role in many systems including intracellular signalling to enable the integration and regulation of metabolic processes, the transmission of information via the nervous system, the control of muscle contraction (including the heart) and blood clotting. Furthermore, it has been suggested that adequate calcium intake (for example from reduced fat dairy products) may help lower high blood pressure and may help protect against colon cancer, although more evidence is needed to fully substantiate these functions.

The skeleton contains about 99% of the body's calcium with approximately 1kg present in adult bones. The major constituents of bone are calcium and phosphate, forming hydroxyapatite, which is associated within a meshwork of collagen fibres to form a rigid structure. The body's requirement for calcium fluctuates with the rate of bone development, so as well as protecting vital organs, the skeleton acts as a 'bank' of minerals from which calcium and phosphorus may be continually withdrawn or deposited to support physiological requirement.

Calcium levels in the blood are carefully regulated and blood plasma levels are maintained within narrow limits. Calcium absorption is well controlled to match the needs of the body and so calcium balance can be maintained at a variety of different levels of calcium intake. These sites are regulated by feedback mechanisms controlled by several hormones including parathyroid hormone and the activated form of vitamin D. Plasma levels of calcium only become abnormal if there is a breakdown of this homeostatic mechanism, and not usually as a result of differences in dietary calcium intake. The body invests this effort because small variations in plasma calcium concentrations may have serious consequences to the functioning of vital organs and to health in general. Low blood calcium is called hypocalcaemia and high blood calcium is called **HYPERCALCAEMIA.**

Deficiency

For some nutrients, nutritional deficiency is identified by the existence of a low blood level of the nutrient but for nutrients such as calcium, for the reasons described above, low blood levels rarely occur. Because of the need to maintain blood levels, the impact of a poor supply of calcium is usually reflected in bone density because bone acts as a reservoir in times of need. For example, insufficient calcium in bones can result from an inadequate supply of vitamin D which is essential for absorption of calcium. In children, vitamin D deficiency results in rickets and, in adults, osteomalacia, in which bones become weak owing to lack of calcium.

In terms of dietary supply, a significant proportion of young women have average calcium intakes below the Lower Reference Nutrient Intakes (8% of women aged 19-24 years and 6% of women aged 25-34 years) indicating these intakes are likely to be inadequate. An adequate calcium intake is vital for health, particularly in times of growth (in childhood, adolescence, pregnancy) to establish peak bone mass and also during lactation (breastfeeding). Supplements are sometimes recommended for those at risk of osteoporosis. See nutrient requirements for information on calcium requirements throughout the life course.

Adverse effects

Obtaining calcium as part of a varied diet is unlikely to cause any adverse effects but taking high dose supplements sometimes causes stomach pain and diarrhoea.

Food sources

Milk, cheese and other dairy products provide about half of the calcium in the UK diet. Bread is also an important source in the UK because most bread flour (though not wholemeal) is fortified with calcium by law. Calcium is also provided by some green leafy vegetables such as broccoli and cabbage (but not spinach), fortified soya products and fish eaten with the bones such as sardines, tinned salmon and whitebait.

Calcium absorption

Calcium absorption is influenced by a number of promoting and inhibitory factors. Promoting factors include vitamin D, lactose, dietary protein, non-digestible oligosaccharides and an acidic environment in the small intestine. Calcium is most readily absorbed from milk and dairy products. Inhibitory factors include phytates (e.g. in wholegrain cereals, pulses), oxalate (e.g. from spinach, rhubarb, beetroot), use of antacids, unabsorbed dietary fats, excessive intakes of dietary fibre and large intakes of phosphoric acid (e.g. from carbonated drinks). Calcium is often less available from plant foods where the calcium may be bound by phytates and oxalates in foods, which makes the calcium unavailable for absorption from the intestine into the blood. However, absorption from some plant foods is good e.g. broccoli, although the amount present is usually lower than in milk.

Sodium

Sodium is responsible for regulating body water content and electrolyte balance. The control of blood sodium levels depends on a balance between sodium excretion and absorption at the kidneys, which is regulated by nerves and hormones. Sodium is also required for the absorption of certain nutrients and water from the gut. Sodium is a component of common salt, known as sodium chloride (NaCl).

Deficiency

As with some other minerals, sodium levels in blood and tissues are under homeostatic control. The kidneys tightly regulate sodium concentration and can make the urine almost salt-free or excrete sodium in urine when supply is excessive. Sodium intakes in the UK are considered to be too high and so deficiency of sodium is unlikely but under some circumstances losses can occur:

- Excess sweating:, e.g. due to exercise in a hot environment, may cause some sodium depletion.
- Diarrhoea can cause fluid loss and dehydration leading to some sodium depletion.

- The kidneys normally act to protect the body's stores of sodium, but in Addison's disease failure to produce aldosterone (hormone that allows the kidneys to retain sodium and water) leads to the kidneys inability to conserve sodium.
- Renal failure: The kidneys may also lose sodium in some types of renal failure.
- Drugs: Diuretic drugs may remove large amounts of sodium in the urine.

Adverse effects

High sodium intakes, along with obesity and high alcohol intake, are considered to be among the risk factors for high blood pressure (hypertension), which is a risk factor for cardiovascular disease and stroke. A low salt diet may be used in the treatment of hypertension.

Food sources

Most raw foods contain very small amounts of sodium chloride (salt). But salt is often added during the processing, preparation, preservation and serving of foods.

Potassium

Potassium is essential for water and electrolyte balance and the normal functioning of cells, including nerves. Increased dietary intakes of potassium have been associated with a decrease in blood pressure, as it promotes loss of sodium in the urine. It is suggested that an increase in potassium intakes may offset the impact of some of the sodium in the diet, therefore helping to protect cardiovascular health.

Deficiency

Low blood potassium levels (HYPOKALAEMIA) can result from severe diarrhoea. Symptoms include weakness, mental confusion and, if extreme, heart failure.

Adverse effects

High supplementary doses of potassium can be harmful especially if the kidneys are not functioning properly.

Food sources

Potassium is present in almost all foods but fruit (particularly bananas), vegetables, meat, fish, shellfish, nuts, seeds, pulses and milk are useful sources. Processed foods typically contain less than raw foods.

Iron

Iron is essential for the formation of haemoglobin in red blood cells; haemoglobin binds oxygen and transports it around the body. Iron is also an essential component in many enzyme reactions and has an important role in the immune system. In addition, it is required for normal energy metabolism and for the metabolism of drugs and foreign substances that need to be removed from the body.

Deficiency

A lack of dietary iron depletes iron stores in the body and this can eventually lead to IRON DEFICIENCY ANAEMIA. In particular, women of child bearing age and teenage girls need to ensure they consume adequate dietary iron because their requirements are higher than those of men of the same age. Also, loss of blood due to injury or large menstrual losses increases iron requirements in the short term. Data from the NDNS indicate that average daily iron intakes from foods are below the RNI for women in all age groups, except for older women (over the age of 54 years).

Currently, there are no recommendations for increasing iron intake during pregnancy as the extra demand should be offset by pre-existing body stores, lack of menstrual blood loss and the increased intestinal absorptive capacity of the mother during the second and third trimesters of pregnancy.

More than 2 billion people worldwide suffer from iron deficiency anaemia, making it the most common nutritional deficiency condition.

Adverse effects

As with some other minerals, under normal circumstances absorption of iron is tightly controlled as iron can have adverse effects owing to its ability to generate oxygen free radicals. However, 1 person in 200 of northern European descent is genetically predisposed to the iron loading disease HAEMCHROMATOSIS.

Food sources

Dietary iron is found in two basic forms. Either as haem iron (from animal sources) or non-haem iron (from plant sources). Haem iron is the most bioavailable form of iron. However, the predominant form of iron in all diets is non-haem iron, found in cereals, vegetables, pulses, beans, nuts and fruit. Absorption of non-haem iron is affected by various factors in food. Phytate (in cereals and pulses), fibre, tannins (in tea) and calcium can all bind non-haem iron in the intestine, which reduces absorption. However, vitamin C, present in fruit and vegetables, aids the absorption of non-haem iron when eaten at the same time, as does meat.

Liver, red meat, pulses, nuts, eggs, dried fruits, poultry, fish, whole grains and dark green leafy vegetables are all sources of iron. Since the 1950s in the UK, all wheat flours (other than wholemeal) have been fortified with iron and many breakfast cereals are also fortified with iron and so contribute to iron intake,

Trace elements

Zinc

The major function of zinc in human metabolism is as a cofactor for numerous enzymes. Zinc has a key role as a catalyst in a wide range of reactions. It is directly or indirectly involved in the major metabolic pathways concerned with protein, lipid, carbohydrate and energy metabolism and is also essential for cell division and, therefore, for growth and tissue repair and for normal reproductive development. In addition, zinc is required for the functioning of the immune system and in the structure and function of the skin, and hence plays a vital role in wound healing.

Deficiency

In some countries, delayed puberty and small stature have been linked to zinc deficiency, though it is not certain that this is due to zinc deficiency alone.

Adverse effects

Excess zinc in the body from very high doses can interfere with copper metabolism.

Food sources

Zinc is present in many foods and is most readily absorbed from meat. It is also present in milk, cheese, eggs, shellfish, wholegrain cereals, nuts and pulses. For cereals and pulses, zinc's availability is limited by phytates.

Iodine

Iodine is an essential component of the thyroid hormones, thyroxine and triidothyronine, which are vital regulators of metabolic rate and of physical and mental development.

Deficiency

Iodine deficiency results in lethargy and swelling of the thyroid gland in the neck which forms a goitre.

Adverse effects

Excess iodine is not absorbed so toxicity is unlikely in healthy individuals.

Food sources

The amount of iodine in plant foods such as vegetables and cereal grains is determined by the amount of iodine in the growing plant's environment, and the amount in the soil or water can vary dramatically. The only rich sources of iodine are seafoods (sea fish, shellfish and seaweed), but milk is also a source. In some countries certain foods, e.g. salt and bread, are fortified with iodine.

Fluoride

Function

1. The main function of fluoride in the body is in the mineralisation of bones and teeth.
2. Fluoride also protects the teeth from dental caries (tooth decay) and is now routinely added to most toothpastes.

Adverse effects

In rare cases, very large amounts of (non-dietary) fluoride can cause FLUOROSIS.

Symptoms: may be mild such as mottling and crumbling of the teeth, or more severe causing skeletal changes such as calcification of ligaments and tendons which leads to muscle, joint and bone problems.

Source: Fluoride is found in fluoridated water, tea and fish. The diet provides only about 25% of total intake. The addition of fluoride to toothpaste is important in those areas where the water supply is low in fluoride.

Selenium

Function

The main function of selenium is as a component of some of the important antioxidant enzymes (e.g. glutathione peroxidase), and therefore to protect the body against oxidative damage. It is also necessary for the use of iodine in thyroid hormone production, for immune system function and for reproductive function.

Deficiency disorder :The best characterised selenium deficiency condition is Keshan disease, a heart condition that affects children and women of child-bearing years in rural China where soils are deficient of selenium, leading to continuing low levels in the food chain.

Adverse effects

In excess selenium is exceedingly toxic. Symptoms of **selenosis** (selenium excess) include brittle nails and hair, skin lesions and garlic odour on the breath.

Source: Selenium is found in a variety of foods, especially Brazil nuts, bread, fish, meat and eggs. The selenium content of cereals is directly proportional to the selenium content in the soil.

Chromium

Chromium (III) is the active form of this nutrient and its main functions appear to be linked with carbohydrate and lipid metabolism. This form of chromium is thought to promote the action of insulin, the hormone which controls glucose levels in the blood. Subjects with adequate dietary chromium have improved control over blood glucose and a better blood lipid profile.

One significant characteristic of chromium deficiency is impaired glucose tolerance, which can be improved by chromium supplementation. However, chromium supplementation does not improve insulin action for people who were not initially deficient.

Chromium is not known to show toxicity.

Source: Sources of chromium include meat, nuts, cereal grains, brewer's yeast and molasses.

Functions

Chromium is an essential mineral that is not made by the body

1. Chromium is important in the breakdown of fats and carbohydrates.
2. It is important for brain function and other body processes.