S6 FOODS AND NUTRITION

WATER-SOLUBLE VITAMINS

Vitamin B_1 (Thiamin)

Historically thiamin deficiency affecting the peripheral nervous system (beriberi) was a major public health problem in South-East Asia following the introduction of the steam-powered mill that made highly polished rice widely available. More commonly, thiamin affecting the heart and the central nervous system is a problem in people with an excessive consumption of alcohol to the extent that it was seriously suggested in Australia at one time that thiamin should be added to beer. However, some studies have found that alcohol inhibits transport of thiamin, which may explain why alcoholics are susceptible to thiamin deficiency.

Nature of thiamin

- Its name comes from its chemical ring-like structure, which is a thiazole ring (compound that contains both sulphur and nitrogen)
- Was first isolated from rice polishing
- It is highly water soluble
- Like other water-soluble vitamins, thiamin is readily lost by leaching into cooking water.
- Furthermore, it is unstable to light, although bread and flour contain a significant amounts of thiamin, much of all of this may be lost when baked goods are exposed to sunlight in a shop window.
- Thiamin is also destroyed by sulphites and in potato products that have been blanched by immersion in sulphite solution, there is little or no thiamin remaining.
- Polyphenols including tannic acid in tea also destroy thiamin and have been associated with thiamin deficiency.
- Thiamin is destroyed by thiamin degrading enzymes (thiaminases) in raw fish, shellfish.

Functions of thiamin

- Thiamin when combined with phosphorus, it gives a compound called thiamin pyrophosphate (TPP), or thiamin diphosphate which is a coenzyme that plays a key role in the reaction that produces energy from glucose or that converts glucose to fats for tissue energy storage.
- Thiamin triphosphate has a function in nerve conduction.

Thiamin deficiency

Thiamin deficiency may result in three distinct syndromes:

- Chronic peripheral neuritis, beriberi: which may or may not be associated with heart failure and oedema. It includes dry beriberi and wet beriberi.

- Acute pernicious (fulminating) beriberi: shoshin beriberi: in which heart failure and metabolic abnormalities predominate, with little evidence of peripheral neuritis.

- Wernicke's encephalopathy with Korsakoff's psychosis: a thiamin-responsive condition associated especially with alcohol and narcotic abuse.

Dry beriberi

Chronic deficiency of thiamin, especially associated with a high-carbohydrate diet, results in beriberi. Initially the patient complains of weakness, stiffness and cramps in the legs and is unable to walk a long distance. There may be numbness of the dorsum of the feet and ankles, and vibration sense may be diminished. As the disease progresses, the ankle jerk reflex is lost, and the muscular weakness spreads upwards, involving all muscles of the leg. At this stage, the patient is unable to keep either the toe or the whole foot extended off the ground. When the arms are affected, there is a similar inability to keep the hand extended. The affected muscles become tender, and numb. There is deep muscle pain and in the final stage, when the patient is bed-ridden, even slight pressure as from bed clothes, causes considerable pain.

Wet beriberi

The heart may also be affected in beriberi, with dilatation of arterioles, rapid blood flow, increased pulse rate and pressure and increased jugular venous pressure leading to right-sided heart failure and oedema (so called wet beriberi).

Acute pernicious (fulminating) beriberi-shoshin (acute) beriberi

This is characterized by heart failure without increased cardiac output, and no peripheral oedema may also occur acutely, associated with severe lactic acidosis. It mostly occurs among alcoholics.

The Wernicke-Korsakoff syndrome

While peripheral neuritis (***damage to the nerves***) and acute cardiac beriberi with lactic acidosis (***lactic acid build up in the body***) occur in thiamin deficiency associated with alcohol abuse, the more usual presentation is as the Wernicke-Korsakoff syndrome, due to central nervous system lesions. Initially there is a confusion state, Korsakoff's psychosis, which is characterized by loss of recent memory although memory of the past event may be unimpaired. Later, clear neurological signs develop: Wernicke's encephalopathy (a syndrome characterised by confusion, and impairment of short-term memory and nystagmus (fast, uncontrollable movements of the eyes).

Thiamin requirements

Because thiamin has a central role in energy yielding, and especially CHO metabolism, requirements depend mainly on CHO intake.
Reference intakes are calculated on the basis of 0.5mg/1000kcal with a minimum requirement of for people with low energy intake of 0.8-1.0mg/day to allow for the metabolism of endogenous substrates.

Children: 0.5-0.7mg/day
Adult men: 1.0mg/day
Adult women: 0.8mg/day

Food sources of thiamin

Thiamin is widely distributed in foods, but some sources include: Pork, nuts, wholegrain cereals and cereal products (***thiamin is present in the outer germ layers of cereal grains, thus the need of fortification of flour in some countries like the UK***), pulses, meat, and vegetables.

Vitamin B_2 (Riboflavin)

Nature of riboflavin

- Soluble in water
- Stable in presence of heat, oxygen and acid
- Unstable in presence of light or alkali

Functions of riboflavin

- Riboflavin plays a central role as a coenzyme in energy yielding metabolism of proteins and carbohydrates. These coenzymes (flavin adenine dinucleotide (FAD), flavin mononucleotide) also play a role in enzymes involved in tissue respiration.

- Riboflavin is necessary for normal growth and helps maintain the integrity of mucus membranes, skin, eyes and the nervous system.

Riboflavin deficiency

Although riboflavin is involved in all areas of metabolism, and deficiency is widespread on global scale, deficiency is not fatal. There seem to be two reasons for this:

- Although deficiency is common, the vitamin is widespread in foods, and most diets will provide minimally adequate amounts to permit maintenance of central metabolic pathways.

- In deficiency, there is extremely efficient reutilization of the riboflavin that was used during protein metabolism so that only a very small amount is metabolized or excreted.

However, deficiency results in a riboflavinosis, characterized by:

- Cracks and sores in the skin around the mouth and lips (angular stomatitis and cheilosis)
- Inflammation of the tongue (glossitis)
- A painful desquamation of the tongue so that it is red, dry and atrophic (magenta tongue)
- Anaemia as a result of iron deficiency due to impaired iron absorption.

Requirements of riboflavin

Children: 0.6-1.0 mg/day
Adult men: 1.3mg/day
Adult women: 1.1mg/day

Food sources of riboflavin

Milk and dairy products, eggs, liver and offal meats, green leafy vegetables, yeast.

Vitamin B_3 (Niacin)

Niacin is not strictly a vitamin as it can be synthesized in the body from the essential amino acid tryptophan. It is only when tryptophan metabolism is affected that dietary preformed niacin becomes important. Two compounds nicotinic acid and nicotinamide have the biological activity of niacin.

Functions of niacin

The best-defined role of niacin is in oxidation and reduction reactions in glycolysis, as the functional nicotinamide part of the coenzymes NAD (nicotinamide adenine dinucleotide) and NADP (nicotinamide adenine dinucleotide phosphate).

Niacin deficiency

Niacin becomes deficient only when there is deficiency of the essential amino acid tryptophan. The resultant efficiency disease is called pellagra.

Pellagra is characterized by photosensitive *dermatitis (**inflammation of the skin/rash**)*, like severe sunburn, affecting all parts of the skin that are exposed to sunlight. Similar lesions may be present in areas, not exposed to sunlight but subject to pressure, such as knees, elbows, wrists and ankles.

Advanced pellagra is also associated with *dementia (**serious loss of global cognitive ability)*** and there may be *diarrhoea.* Thus, some people call those symptoms 3 Ds of pellagra: dermatitis, dementia, and diarrhoea.

Niacin requirements

Related to total calories in the diet: 6.6mg/1000kcal.

Children: 8-12 mg/day
Adult men: 17mg/day
Adult women: 13mg/day

Food sources

Meat, fish, cereals and cereal products, wholegrain etc

Vitamin B_6 (pyridoxine)

The generic descriptor of vitamin B_6 includes the alcohol *pyridoxine,* the aldehyde *pyridoxal,* and the amine *pyridoxamine.* These compounds are interconvertible, and have equal biological activity. They are all converted in the body to the metabolically active form, *pyridoxal-5- phosphate.*

Functions of vitamin B6

Pyridoxal-5-phosphate is a coenzyme in there many areas of metabolism:

- In a wide variety of reactions of amino acids (protein metabolism), and in CHO and fat metabolism
- Synthesis of haem
- Conversion of tryptophan to niacin
- In the regulation of the action of steroid hormones e.g.: estrogen

- It has been found that vitamin B_6 supplements are useful in overcoming side-effects of oral contraceptives
- Vitamin B_6 supplements also have been found useful in the treatment of post-menstrual syndrome.

Vitamin B_6 deficiency

Deficiency of vitamin B_6, severe enough to lead to clinical signs is extremely rare. However, deficiency results in abnormalities in amino acid metabolism, especially tryptophan and Methionine. It also leads to convulsions. It can also lead to increased sensitivity to steroid hormone action. This may lead to hormone-dependent cancers such as cancer of breasts, uterus and prostate. Vitamin B_6 supplements may be a useful adjunct to other therapy in these common cancers.

Vitamin B_6 requirements

Requirements of vitamin B_6 depend on protein intake, since it highly needed in the metabolism of proteins. The reference intake is 15-16 μg/g of dietary protein.

Children: 0.7-1.0 mg/day
Adult men: 1.4mg/day
Adult women: 1.2mg/day

Food sources of vitamin B_6

Pyridoxine is found in both plant and animal foods; pyridoxal and pyridoxamine are only present in animal products

Meat, poultry, fish, egg yolk, whole grains, bananas, potato, dried beans, lentils, chickpeas.

Vitamin B_{12} (Cobalamin)

There are several related structures with vitamin B_{12} activity called cobalamins; all consist of a porphyrin ring surrounding a cobalt atom. These compounds are synthesized by micro-organisms and are not found in plants.

Dietary deficiency of vitamin B12 occurs only in strict vegans, as the vitamin is found almost exclusively in animal foods. However, functional deficiency as a result of impaired absorption is relatively common, especially in elderly people with atrophic gastritis, a condition characterized by chronic inflammation of the stomach, accompanied by a diminished size and functioning of the mucosa and glands.
The active vitamin B12 is also known as cyanocobalamin.

Functions of vitamin B12

There are 3 vitamin B_{12}-dependent enzymes: methylmalonyl-CoA mutase, leucine aminomutase, and Methionine synthetase. So, vitamin B12 has a basic coenzyme function, closely related to amino acid metabolism. It also plays a role in the metabolism of folic acid.

Vitamin B_{12} deficiency

Deficiency is rare as, unlike most water-soluble vitamins, vitamin B_{12} can be stored in the liver. However, deficiency causes pernicious anemia (the release into the blood of immature precursors of RBCs). This is because vitamin B_{12} is involved in folic acid metabolism, and folic acid in turn, is involved in the formation of RBCs (red blood cells). Commonest cause of pernicious anemia is failure of absorption of vitamin B_{12} rather than dietary deficiency. This may be due to failure of ***intrinsic factor*** (*a special protein released in the stomach*) secretion because gastric parietal cells have an abnormality and are not able to secrete this factor.

In vitamin B_{12} deficiency, there might be also peripheral nerve damage, which leads to burning foot syndrome.

Vitamin B_{12} requirements

It is present in virtually all animal tissues, plants contain no vitamin B_{12}. The reference intake for adults is 1.4-2.0 μg/day and children is 0.5-1.0μg/day.

Food sources of vitamin B_{12}

Meat, liver, kidney, chicken, fish, eggs, milk and milk products.

Folic acid (Folate)

Folic acid is metabolically closely related to vitamin B_{12}. Deficiency of either vitamin has similar clinical effects, and effects of folate metabolism exert the main effects of vitamin B_{12} deficiency. Although folate is widely distributed in foods, dietary deficiency is not uncommon, and a number of commonly used drugs can cause folate depletion.

Functions of folate

Folate functions as a coenzyme in many metabolic reactions, such as those involved in synthesis of DNA and RNA. And hence plays a crucial role in cell division.

It is also useful in the prevention of neural tube defects and pregnant women are recommended to take supplements. Neural tube defects are malformations of the brain, spinal cord, or both during embryonic development. The closure of neural tube happens in the first month of pregnancy, and if there is folate deficiency during this period, the abnormality develops. Women are recommended to take 400μg/day at least one month before conception.

Folate deficiency

Folate deficiency diseases include:

- *Megaloblastic anemia:* circulating immature RBCs. This is because folate is involved in the formation of RBCs, and if there is deficiency of folate, the formed RBCs will be immature, not capable of transporting enough oxygen, leading to anemia.

- *Neural tube defects:* more common is spina bifida (a birth defect in which the backbone and spinal canal do not close before birth)

Requirements

Reference intake: 3 μg/kg body weight

Children: 70-150 μg/day
Adults: 200 μg/day

Food sources of folate

Green leafy vegetables (losses from cooking are high), fresh fruits (especially orange juice), dried beans, peas, nuts, egg yolk, mushrooms, banana, liver.

Biotin

Biotin was originally discovered as part of the complex called *bios,* which produced the growth of yeast and separately as vitamin H, the protective or curative factor in "egg white injury", the disease cased in man and experimental animals by feeding diets containing large amounts of uncooked egg white. Biotin is widely distributed in many foods.

Functions of biotin

Biotin is a cofactor for several enzyme systems involved in the synthesis of fatty acids and in gluconeogenesis.

Deficiency of biotin

Biotin is widely distributed in foods and deficiency is unknown except in people maintained for many months on TPN (Total Parenteral Nutrition) and a very small amount of people who eat abnormally large amounts of uncooked eggs (there is a protein in egg white called ***avidin***, that binds biotin extremely and makes it unavailable for absorption. However, cooking denatures this protein.)

Biotin requirements
Average intake: 100-200 μg/day.

Food sources of biotin
Dried beans, egg yolk, mushrooms, banana, grapefruits, watermelon, liver etc.

Pantothenic acid

Pantothenic acid (sometimes known as vitamin B5) is widely distributed in all foodstuffs, the name derives from the Greek for" from everywhere", as opposed to other vitamins which are found in some foods, not all. As a result, pantothenic deficiency has not been reported.

Functions of pantothenic acid

It has a central role in energy-yielding metabolism, and in the biosynthesis of fatty acids.

Its basic role as an essential constituent of the body's key activating agent acetyl CoA, thus pantothenic acid is vital to metabolic reactions involving CHO, fats and protein requirements.

Pantothenic acid deficiency

Experimental pantothenic acid depletion results in the following symptoms: muscle weakness, mental depression, GI disturbances, and decreased serum cholesterol.

Requirements

Average intake: 3-7mg/day

Food sources

It is found in all foods but rich sources are offal, peanuts, meat, egg yolk, most vegetables, and most cereals.

Vitamin C or (Ascorbic acid)

Vitamin C is a vitamin for only a limited number of vertebrates such as man, some birds and most fishes. There is active transport of the vitamin at he intestinal mucosal brush boarder membrane.

Nature of vitamin c

- The structure of vitamin C is similar to that of glucose, its metabolic precursor in most animals, but humans lack a specific enzyme needed to change glucose to ascorbic acid.
- Vitamin C is an unstable and easily oxidized acid
- It can be destroyed by oxygen, alkalis, and high temperatures

Functions of vitamin C

- It serves as a coenzyme in some metabolic reactions
- Vitamin C helps to build and maintain body tissues in general including bone matrix, cartilage, and connective tissue as it is involved in the formation of collagen
- Vitamin C assists in the absorption of non-haem iron as it converts the ferric (Fe^{3+}) ion to the more soluble ferrous (Fe^{2+} form)
- Vitamin C is an important antioxidant helping to prevent free radical damage

Vitamin C deficiency

Vitamin C deficiency leads to a disease called ***scurvy,*** a hemorrhagic disease in which diffuse tissue bleeding occurs, limbs and joints are painful and swollen, bones thicken because of subperiosteal hemorrhage, bones fracture easily, wounds do not heal well, gums are swollen and bleeding and teeth loosen.

Vitamin C requirements

Recommended daily allowance (RDA): 90 mg/day: men
75 mg/day: women

Food sources of vitamin C

Citrus fruits, guava, mango, papaya, green leafy vegetables, tomatoes.