7. Thiamin

Physiology and metabolism

The principal metabolic function of thiamin (vitamin B_1) is as the precursor for thiamin diphosphate (thiamin pyrophosphate), which is the coenzyme for a number of reactions involved in carbohydrate and branched-chain amino acid metabolism and central energy-yielding metabolic pathways. In addition thiamin triphosphate has a role in the propagation of nerve impulses in the nervous system [1]. Most thiamin in foods is present as phosphates, mainly thiamin diphosphate. These phosphates are hydrolysed by phosphatases in the intestinal lumen; free thiamin is absorbed in the upper small intestine. The absorption of thiamin is impaired by alcohol. While intestinal mucosal cells take up thiamin normally in the presence of alcohol, there is impaired transport from the cells into the circulation [2]. Some thiamin is phosphorylated to thiamin monophosphate during absorption, or on passage through the liver.

Both free thiamin and thiamin monophosphate circulate at low concentrations in plasma, bound to albumin; they are taken up by tissues, and converted to thiamin diphosphate (and thiamin triphosphate in nerve tissue). At high intakes, when the albumin binding capacity is saturated, the excess (unbound) vitamin is rapidly excreted in the urine. A small amount of thiamin is excreted in the urine unchanged (normally about 3% of a test dose). The major excretory metabolite is thiochrome, although some 20 additional metabolites are excreted in small amounts. There is little storage of thiamin in the body, and metabolic abnormalities develop within a few days of initiating a thiamin-deficient diet.

Deficiency and excess

Thiamin deficiency can result in three distinct syndromes.

(i) Beriberi, a chronic peripheral neuritis, which may or may not be associated with heart failure and oedema.

(ii) Acute pernicious (fulminating) beriberi, in which heart failure and life-threatening metabolic acidosis predominate, with little or no evidence of peripheral neuritis.

(iii) Central nervous system disturbances, Wernicke's encephalopathy with Korsakoff's psychosis. This is most commonly associated with alcoholism and narcotic abuse.

In general, an acute deficiency is involved in the central nervous system lesions of the Wernicke-Korsakoff syndrome, and a relatively high energy intake is a predisposing factor. Beriberi is more commonly associated with a more prolonged, less severe, deficiency, together with a generally low food intake. A higher intake of carbohydrate and physical activity predispose to the development of heart failure and oedema.

The intestinal absorption of thiamin is readily saturated, and no more than about 2.5 mg can be absorbed in a single dose. Thiamin in the bloodstream which is not bound to plasma proteins is rapidly excreted in the urine [8]. There is no evidence of toxicity of thiamin taken by mouth, at intakes of up to 500 mg/day (for 1 month).

Requirements

Adults

Because the principal metabolic role of thiamin is in energy-yielding metabolism, and especially in carbohydrate metabolism, the requirement is related to energy intake. Saturation of the red cell enzyme transketolase with its coenzyme, thiamin diphosphate, provides a convenient means of assessing the adequacy of body reserves of thiamin. This is generally expressed as the transketolase activation coefficient – the ratio of enzyme activity with added thiamin diphosphate/ that without added coenzyme.

Clinical signs of deficiency are seen in subjects receiving less than 30 µg/MJ, so this is obviously an inadequate intake. In a long-term feeding study, an intake of 45 µg/MJ led to a progressive decline in urinary excretion, falling to 15 µg/24h after 20 months. There were no clinical signs of deficiency, but after 30 months there was an impairment in the metabolism of a test dose of glucose [3,4]. This intake is therefore marginally inadequate.

In depletion / repletion studies, intakes of about 50 µg/MJ are adequate to maintain urinary excretion above 15 µg/day. The average requirement for the maintenance of a normal erythrocyte transketolase activation coefficient is 72 µg/MJ [5,6]. Allowing for individual variation, this gives a PRI of 100 µg/MJ. For people on energy intakes of less than 8 MJ/d, thiamin requirements may not be related directly to energy intake. For them a PRI of 0.8 mg/d is suggested.

Maximum activity of erythrocyte transketolase and complete saturation of the enzyme with its coenzyme require an intake of 140-190 μg/MJ [7]. There is no evidence that this confers any benefit, or is a desirable aim.

Other age groups

There is no evidence that thiamin requirements of women differ from those of men, other than as affected by energy expenditure, or that children, adolescents or the elderly have different requirements /MJ energy intake.

Pregnancy and lactation

In pregnancy and during lactation thiamin requirements/MJ energy intake are unchanged. The thiamin produced in the milk should be covered by the extra amount accompanying the increased energy intake.

Summary

The requirement for thiamin depends on the utilisation of energy-yielding substrates. It therefore increases with the energy expenditure.

Average requirement	72 µg/MJ
Population Reference Intake	100 µg/MJ
Lowest Threshold Intake	50 µg/MJ

These can be expressed for average energy expenditure in mg thiamin/d.

Adults	*Males*	*Females*
Average requirement	0.8	0.6
Population Reference Intake	1.1	0.9
Lowest Threshold Intake	0.6	0.4
Pregnancy		1.0 *
Lactation		1.1

* From 10th week of pregnancy

Population Reference Intakes for younger age groups

	Age Group	PRI (mg/d)
	6 - 11 m	0.3
	1 - 3 y	0.5
	4 - 6 y	0.7
	7 - 10 y	0.8
Males	11 - 14 y	1.0
	15 - 17 y	1.2
Females	11 - 14 y	0.9
	15 - 17 y	0.9

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