

6 Thiamin (Vitamin B₁)

6.1 Introduction

Thiamin (also known as vitamin B₁ or aneurin) was the first B vitamin discovered. Deficiency of the vitamin results in the disease beri-beri, the first nutrient deficiency studied in Malaya in the beginning of the 20th century.

Thiamin functions as the co-enzyme thiamin pyrophosphate (TPP) in the metabolism of carbohydrates and branched-chain amino acids. TPP, coordinated through magnesium (Mg⁺⁺), participates in two main types of metabolic reactions: (a) the formation of α-ketols (eg among hexose and pentose phosphates) as catalysed by transketolase; and (b) in the oxidation of α-keto acids (eg pyruvate, α-ketoglutarate and branched-chain α-keto acids) by dehydrogenase complexes. Hence, thiamin deficiency will result in overall decrease in carbohydrate metabolism and its inter-connection with amino acid metabolism (via α-keto acids). Severe consequences can arise, eg decrease in the formation of acetylcholine for neural function.

6.2 Deficiencies

Thiamin deficiency results in the disease called beri-beri, which has been classically considered to exist in dry (paralytic) and wet (oedematous) forms. Beri-beri occurs in human-milk-fed infants whose nursing mothers are deficient in the vitamin. It also occurs in adults with high carbohydrate intakes mainly from milled rice and intakes of foods containing anti-thiamin factors.

The clinical signs of deficiency include anorexia; weight loss; mental changes such as apathy, decrease in short-term memory, confusion and irritability; muscle weakness; and cardiovascular effects such as an enlarged heart. In wet beri-beri, edema occurs; in dry beri-beri, muscle wasting is obvious. In infants, cardiac failure may occur rather suddenly. In relatively industrialised nations, the neurologic reflections of Wernicke-Korsakoff syndrome are frequently associated with chronic alcoholism with limited food consumption.

Clinically manifest thiamin deficiency is rare today, although some segments of the populations could be on marginal or sub-marginal intakes of the vitamin. Symptoms are less prominent in sub-clinical deficiencies and may include tiredness, headache and reduced productivity.

In Malaysia, in the early part of the 20th century, beri-beri was found to be prevalent amongst migrant workers working in camps, consuming primarily a polished rice diet. The Institute for Medical Research (IMR) embarked on a series of intensive studies into the cause of the disease, beginning 1900. It was also the first nutrient deficiency studied in the country. Various hypotheses on the aetiology of the disease were proposed and actively investigated. Although the IMR researchers were not the first

to discover that thiamin deficiency was the cause of the disease, they contributed significantly to the prevention and cure of the disease. Their efforts in distributing methods for the preparation of extracts of rice polishings to hospitals and dispensaries for the treatment of beri-beri patients and the prohibition of the use of white polished rice helped to control the disease (Tee *et al.*, 2000).

Since the 1950s, there have been no further reports of clinically manifest vitamin B₁ deficiency in the country. Very few reports of subclinical thiamin deficiency in any age group have been documented. Indeed very few biochemical studies on the status of thiamin have been undertaken, due to lack of laboratory facilities for the required analyses. A major study of the nutritional status of various communities in poverty villages in Peninsular Malaysia included the determination of urinary excretion of thiamin in 1170 subjects. The prevalence of "low" excretors varied with different age groups, with most groups having a prevalence of about 25%, indicating the need to improve vitamin B₁ intake in these groups (Chong *et al.*, 1984).

The problem seems to have been practically eliminated over the years, although it cannot be ruled out that certain segments of the community, eg elderly could have marginal deficiencies of the vitamin.

6.3 Food sources

Thiamin is found in a wide variety of foods of plant and animal origin. But only a few foods, including yeast, lean pork and legumes can be considered as good sources of the vitamin (Tee *et al.*, 1997). Yeast contains an extraordinary amount of the vitamin; a commercial yeast extract has a content of up to 0.6 mg/100 g. Pork and pork products eg lean pork, ham and sausage contain high concentrations of thiamin of close to 0.9 mg/100 g. Other meat products such as beef, chicken and duck have much lower amounts of the vitamin, generally about 0.1 mg/100 g. A commercial brand of beef extract has an exceptionally high level of thiamin (1.6 mg/100 g), but this is usually taken in small amounts. Fish and shell fish contain even less thiamin. Various types of legumes, eg chickpea, dhal, green gram and red gram and soya bean contain thiamin ranging from 0.4 to 1.7 mg/100 g bean.

There are also several processed products in the market, especially bread, cereal products and biscuits, that are fortified or enriched with thiamin and several other B vitamins and can become important sources of the vitamin.

Fruits are poor sources of thiamin, containing in general not more than 0.03 mg/100 g. Vegetables contain slightly more thiamine but are generally less than 0.1 mg/100 g and are therefore not good sources as well.

6.4 Factors affecting requirements

There are no studies that have examined the effect of energy intake on thiamin requirement. There is also no agreement as to whether expressing thiamin requirements in absolute terms is more useful for predicting biochemical thiamin status than expressing it in relation to energy intake. Despite the lack of direct experimental data, the known biochemical function of thiamin as thiamin pyrophosphate (TPP) in the metabolism of carbohydrate suggests that at least a small (10%) adjustment to the estimated requirement to reflect differences in the average energy utilisation and size of men and women, a 10% increase in the requirement to cover increased energy utilisation during pregnancy, and a small increase to cover the energy cost of milk production during lactation appears to be necessary (IOM, 1998).

Heavy exercise under certain conditions may increase the requirement for thiamin as well as other vitamins. However, the observations on the effects of physical activity on thiamin requirement have been inconsistent, the effects small and the experimental conditions highly variable. It was thus concluded that under normal conditions, physical activity does not appear to influence thiamin requirements to a substantial degree. However, those who are engaged in physically demanding occupations or who spend much time training for active sports may require additional thiamin (IOM, 1998).

There are no studies that directly compare the thiamin requirements of males and females. A small (10%) difference in the average thiamin requirements of men and women is assumed on the basis of mean differences in body size and energy utilisation.

6.5 Setting requirements and recommended intakes of thiamin

There are no known local studies on thiamin requirements of communities that the Technical Sub-Committee (TSC) on Vitamins could use as a reference when considering RNI for the vitamin. There are also very few reports of the biochemical status of the vitamin amongst the population groups. The TSC therefore referred to the FAO/WHO (2002) consultation report and the IOM (1998) DRI recommendations. The rationale and steps taken in setting requirements and the levels recommended by these organisations as well as available reports of thiamin status of communities in the country were considered. The TSC on Vitamins decided to adapt the FAO/WHO (2002) values as the revised RNI for Malaysia, given in bold in the following paragraphs according to age groups and summarised in Appendix 6.1.

Infants

The recommendation intake for young infants is based on observed mean intake data from infants fed human milk exclusively during their first 6 months as well as the thiamin concentration of milk produced by well-nourished mothers. The FAO/WHO

Consultation estimated that the mean thiamin content of human milk is 0.21 mg/l which corresponds to 0.16 mg thiamin per 0.75 L of secreted milk per day. The Consultation rounded the figure and set the requirement at 0.2 mg/day for infants 0-6 months (FAO/WHO, 2002).

For the group 6-11 months, in addition to thiamin from breast milk, the intake of solid food has also to be taken into account. Thus the average requirement was calculated to be 0.3 mg/day.

RNI for infants

0 - 5 months	0.2 mg/day
6 - 11 months	0.3 mg/day

Children 1 - 9 years

There appears to be no direct data on which to base the estimated average requirement for children 1-9 years. The RDA for these age groups have thus been determined by IOM (1998) by extrapolating downwards from the average requirement of young adults by adjusting for metabolic body size and growth and adding a factor for variability. The RDA for thiamin is set by assuming a coefficient of variation (CV) of 10% because information is not available on the standard deviation of the requirement for thiamin. As RDA is defined as equal to the estimated average requirement (EAR) plus twice the CV to cover the needs of 97 to 98% of the individuals in the group, therefore, the RDA is 120 % of the EAR.

The FAO/WHO consultation did not provide details on how the recommended intakes were arrived at, but they were similar to those of the IOM (1998).

RNI for children

1 - 3 years	0.5 mg/day
4 - 6 years	0.6 mg/day
7 - 9 years	0.9 mg/day

Adolescents

The Dietary Reference Intakes (DRI) Standing Committee reviewed several studies amongst adolescents in attempting to obtain data to estimate the requirements of thiamin for this age group (IOM, 1998). These included dietary intake studies, status of thiamin, and a controlled-diet dose-response experiment. In the absence of additional definitive information, requirements for these groups were extrapolated from adult values as described above for young children.

Similar to what has been said for the recommended intake for children, the FAO/WHO Consultation did not provide details on how the recommended intakes for adolescents were arrived at, but they were similar to those of the IOM (1998).

RNI for adolescents

Boys 10 – 18 years 1.2 mg/day
Girls 10 – 18 years 1.1 mg/day

Adults and elderly

The same recommendations were made for the intakes of adults by the FAO/WHO Consultation as well as the IOM (1998). No details for the recommendations were given by the former group. The IOM publication referred to several studies that were reviewed, especially a study by Sauberlich *et al.* (1979), who reported a carefully controlled, thiamin depletion-repletion experiment amongst 7 healthy young men. These investigators concluded that thiamin at 0.30 mg/1,000 kcal (approximately 1.0 mg per day) met the minimum requirement for young men as determined by using urinary excretion of thiamin. This value is also close to the average requirement for normal erythrocyte transketolase activity. The requirement for men was thus set at 1.0 mg/day and 0.9 mg/day for women, assuming a 10% decrease for women based on body size and energy needs.

The RDA for thiamin was thus set by assuming a coefficient of variation (CV) of 10% because information is not available on the standard deviation of the requirement for thiamin. RDA is thus defined as equal to the estimated average requirement (EAR) plus twice the CV to cover the needs of 97 to 98 of the individuals in the group, or 120% of the EAR.

In considering the requirements of the elderly, although there are some data to suggest that requirements might be somewhat higher in the elderly than in younger adults, the DRI Standing Committee recognised that there is also a concomitant decreased energy utilisation that may offset this (IOM, 2001). Thus the recommended intake for older adults is the same as those for adults.

RNI for adults

Men 19 – 65 years 1.2 mg/day
Women 19 – 65 years 1.1 mg/day

RNI for elderly

Men > 65 years 1.2 mg/day
Women > 65 years 1.1 mg/day

Pregnancy and lactation

The FAO/WHO Consultation accepted an estimated average total energy cost of 230 MJ for pregnancy. With an intake of 0.4 mg thiamin/4184 kJ, this amounts to a total of 22 mg, or 0.12 mg/day for additional thiamin need for the second and third trimesters (180 days). Taking into account an increased growth in maternal and foetal compartments, an overall additional requirement of 0.3 mg/day was felt to be adequate.

Lactating women are estimated to transfer 0.2 mg thiamin in their milk each day, and an additional 0.2 mg is estimated as a need for the increased energy cost of lactation of about 2092 kJ/day. A total amount of 0.4 mg/day was thus added to the recommended intake for the adult women.

RNI for

Pregnancy	1.4 mg/day
Lactation	1.5 mg/day

Discussions on revised RNI for Malaysia

The RNI values for thiamin for Malaysia, adapted from FAO/WHO (2002), are also the same as those adopted by the Working Group for the Harmonisation of RDAs in SEAsia (2002). Appendix 6.1 provides a summary of these revised RNI, compared with the previous Malaysian RDI of 1975, the FAO/WHO (2002) recommendations and the values recommended by IOM (1998).

For children, the revised RNI are slightly lower than those of the previous Malaysian RDI (Teoh, 1975). For adolescents and adults and pregnant and lactating women, the revised values are slightly higher. The revised RNI is actually similar to that of IOM (1998) but with slight differences in the groupings of children and adolescents of both sexes. The TSC discussed the need to increase the thiamin requirement for older adults, but decided to maintain the RNI to be the same as that for adults because of the generally more sedentary lifestyle and therefore lower energy expenditure of the elderly.

6.6 Toxicity and tolerable upper intake levels

There does not appear to be a problem with thiamin toxicity because renal clearance of levels usually ingested is rapid. There have been no reports of adverse effects from the consumption of excess thiamin by ingestion of food and supplements. Neither the FAO/WHO (2002) nor the IOM (1998) reports provided any indications of toxicity levels. Because the data are inadequate for a quantitative risk assessment, no Tolerable Upper Intake Level (UL) could be derived for thiamin (IOM, 1998).

6.7 Research recommendations

The following priority areas of research are recommended:

- Magnitude of thiamin deficiency among high risk groups such as alcoholic individuals, elderly people and psychiatric patients.
- Efficacy of thiamin supplementation on high risk individuals or groups.
- Determine effects of food preparation and cooking methods on thiamin content of selected foods to enable establishing conversion factors for calculating thiamin losses for a wide variety of foods
- Study nutrient values (including vitamin B content) of the various types of rice available in the market and their claims of health benefits for various chronic diseases.

6.8 References

Chong YH, Tee ES, Ng TKW, Kandiah M, R Hanis Hussein, Teo PH and Siti Mizura S (1984). Status of Community Nutrition of Poverty Kampungs. Institute for Medical Research Bulletin No. 22, Kuala Lumpur; 65 p.

FAO/WHO (2002). Thiamin, riboflavin, niacin, vitamin B₆, pantothenic acid and biotin. In: *Human Vitamin and Mineral Requirements*. Report of a Joint FAO/WHO Expert Consultation. FAO, Rome; pp 27-30.

IOM (1998). Thiamin. In: *Dietary References Intakes for Thiamine, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B₁₂, Pantothenic Acid, Biotin and Choline*. Food and Nutrition Board, Institute of Medicine. National Academy Press, Washington DC; chapter 4, pp 58-86.

Sauberlich HE, Herman YF, Stevens CO, Herman RH (1979). Thiamin requirement of the adult human. *Am J Clin Nutr* 32: 219-222.

Tee ES, Mohd Ismail N, Mohd Nasir A and Khatijah I (1997). *Nutrient Composition of Malaysian Foods*. 4th Edition. Malaysian Food Composition Database Programme, Institute for Medical Research, Kuala Lumpur; 310 p.

Teoh ST (1975). Recommended daily dietary intakes for Peninsular Malaysia. *Med J Mal* 30: 38-42.

Appendix 6.1 Comparison of recommended intake for thiamin (vitamin B₁): RDI Malaysia (1975), RNI Malaysia (2005), RNI of FAO/WHO (2002) and RDA of IOM (1998)

Malaysia (1975)		Malaysia (2005)		FAO/WHO (2002)		IOM (1998)	
Age groups	RDI (mg/day)	Age groups	RNI (mg/day)	Age groups	RNI (mg/day)	Age groups	AI (mg/day)
Infants		Infants		Infants		Infants	
< 1 year	0.4	0 – 5 months	0.2	0 – 6 months	0.2	0 – 6 months	0.2
		6 – 11 months	0.3	7 – 11 months	0.3	7 – 12 months	0.3
							RDA (mg/day)
Children		Children		Children		Children	
1 – 3 years	0.5	1 – 3 years	0.5	1 – 3 years	0.5	1 – 3 years	0.5
4 – 6 years	0.7	4 – 6 years	0.6	4 – 6 years	0.6	4 – 8 years	0.6
7 – 9 years	0.9	7 – 9 years	0.9	7 – 9 years	0.9		
Boys		Boys		Boys		Boys	
10 – 12 years	1.0	10 – 18 years	1.2	10 – 18 years	1.2	9 – 13 years	0.9
13 – 15 years	1.0					14 – 18 years	1.2
16 – 19 years	1.0						
Girls		Girls		Girls		Girls	
10 – 12 years	0.9	10 – 18 years	1.1	10 – 18 years	1.1	9 – 13 years	0.9
13 – 15 years	0.9					14 – 18 years	1.0
16 – 19 years	0.8						-
Men		Men		Men		Men	
20 – 39 years	1.0	19 – 65 years	1.2	19 – 65 years	1.2	19 – 30 years	1.2
40 – 49 years	1.0	>65 years	1.2	>65 years	1.2	31 – 50 years	1.2
50 – 59 years	0.9					51 – 70 years	1.2
≥60 years	0.8					>70 years	1.2
Women		Women		Women		Women	
20 – 39 years	0.8	19 – 65 years	1.1	19 – 65 years	1.1	19 – 30 years	1.1
40 – 49 years	0.8	>65 years	1.1	>65 years	1.1	31 – 50 years	1.1
50 – 59 years	0.8					51 – 70 years	1.1
≥60 years	0.8					>70 years	1.1
Pregnancy		Pregnancy		Pregnancy		Pregnancy	
1 st trimester	0.8		1.4		1.4	14 – 18 years	1.4
2 nd trimester	1.0					19 – 30 years	1.4
3 rd trimester	1.0					31 – 50 years	1.4
Lactation		Lactation		Lactation		Lactation	
1 st 6 months	1.0		1.5		1.5	14 – 18 years	1.4
2 nd 6 months	0.8					19 – 30 years	1.4
						31 – 50 years	1.4