17 Zinc

17.1 Introduction

Zinc as an essential trace element with wide public health and clinical significance has been reviewed by FAO/WHO (2002). The wide distribution of zinc in all body tissues and fluids reflects its essential role in metabolic activity as a component of key cell enzymes. The body's total zinc content ranges from about 1.5 g in women to 2.5 g in men. Skeletal muscle accounts for approximately 60 percent of the total body content and bone mass for approximately 30 percent. Plasma zinc has a rapid turnover rate and it represents only about 0.1 percent of total body zinc content. This level appears to be under close homeostatic control. High concentrations of zinc are found in the choroid of the eye 274 µg/g and in prostatic fluids 300-500 mg/l.

Zinc is an essential component of a large number (>300) of enzymes participating in the synthesis and degradation of carbohydrates, lipids, proteins, and nucleic acids as well as in the metabolism of other micronutrients. Zinc stabilises the molecular structure of cellular components and membranes and contributes in this way to the maintenance of cell and organ integrity. Furthermore, zinc has an essential role in polynucleotide transcription and thus in the process of genetic expression. Its involvement in such fundamental activities probably accounts for the essentiality of zinc for all life forms. Zinc plays a central role in the immune system, affecting a number of aspects of cellular and humoral immunity.

17.2 Food sources

Zinc is widely distributed in foods and is typically associated with the protein fraction and or nucleic fraction of food. Rich sources of dietary zinc include meat (beef, pork), poultry, organ meats (beef, poultry), fish and shellfish and lesser amounts in eggs and dairy products (Table 17.1). Nuts, seeds, legumes and whole grain cereals (especially bran and germ) have relatively high zinc content, while tubers, refined cereals, fruits and vegetables have less. Zinc from foods of animal origin have higher bioavailability than that from foods of plant origin due to the presence of fibre and phytate that inhibit zinc uptake by the intestine.

Table 17.1 Zinc and phytate contents of selected foods

Food	Zinc content mg/100 g	Phytate content mg/100 g	Phytate:zinc molar ratio
Liver, kidney (beef, poultry)	4.2-6.1	0	0
Meat (beef, pork)	2.9-4.7	0	0
Poultry	1.8-3.0	0	0
Seafood	0.5-5.2	0	0
Eggs (chicken, duck)	1.1-1.4	0	0
Dairy (milk, cheese)	0.4-3.1	0	0
Seeds, nuts	2.9-7.8	1760-4710	22-88
Beans, lentils	1.0-2.0	110-617	19-56
Whole-grain cereals	0.5-3.2	211-618	22-53
Refined cereal grains	0.4-0.8	40-349	16-54
Bread (white flour, yeast)	0.9	30	3
Fermented cassava root	0.7	70	10
Tubers	0.3-0.5	93-131	26-31
Vegetables	0.1-0.8	0-116	0-42
Fruits	0-0.2	0-63	0-31

Source: IZiNCG (2004)

17.3 Deficiency

Zinc deficiency can occur through at least five mechanisms – inadequate intake, increased requirements, malabsorption, increased losses and impaired utilization. As the central role of zinc is in cell division and protein synthesis, requirement for zinc therefore increases for growth and development. Infants, children, adolescents, pregnant and lactating women are thus high risk groups of zinc deficiency. The elderly may also be at risk due to inadequate intake and decreased efficiency of zinc absorption. In addition, individuals with malabsorption syndromes (Sprue, Crohn's disease and short bowel syndrome) may also be at risk of zinc deficiency due to malabsorption of zinc and increased urinary zinc losses.

While severe zinc deficiency is rare, mild-to-moderate forms of zinc deficiency may be relatively common worldwide. The detection and estimation of the prevalence of zinc deficiency in the mild-to-moderate states have been difficult due to the lack of adequate laboratory biomarkers and specific clinical features of zinc deficiency states (Hambidge, 2000). Thus, well-designed studies on dietary zinc supplementations have been used to elucidate the prevalence and clinical effects of mild-to-moderate forms of zinc deficiency.

In both humans and animals, zinc deficiency will adversely affect the integrity of the immune system. Impairment to the immune system is associated with increased prevalence of childhood infections. Zinc supplementations are reported to reduce the incidence, duration and severity of acute and chronic diarrheal disease, and the incidence and rates of acute lower respiratory tract infections and malaria among children in developing countries.

Zinc deprivation impairs growth and development of infants, children and adolescents. A meta-analysis of 33 randomized zinc intervention studies to improve children's growth showed that zinc supplements produced highly significant improvements in linear growth and weight gain (average effect sizes of 0.30 – 0.35 SD units) (Brown et al., 2002). Zinc supplementations have also been shown to improve linear growth and weight gain of low birth-weight infants and severely malnourished infants and children. Poor growth and development due to zinc deficiency has been attributed to its depression on appetite. Besides growth, zinc supplementation also improves neurobehavioral functions of infants and children.

Reviews on zinc supplementation trials during pregnancy indicated that maternal zinc deficiency is associated with adverse maternal and fetal outcomes (Caulfield et al., 1998). Preterm labor and pregnancy induced hypertension are possible adverse maternal outcomes of zinc deficiency. Adverse fetal outcomes include intrauterine growth retardation, low birth weight, poor neurobehavioral development and increased morbidity in low birth weight neonates. The findings of eight randomized and controlled intervention trials in less developed countries suggested that maternal zinc supplementation has a beneficial effect on neonatal immune status, early neonatal morbidity and infant infections (Osendarp, West & Black, 2003).

17.4 Factors affecting zinc requirement

Various dietary factors affect the absorption of zinc and consequently zinc requirement. Phytate content of food is an important factor that affects bioavailability of zinc. Phytate is present in plant foods with whole grain cereals, legumes, nuts and seeds having a high content, while fruits, leaves and vegetables have less. Phytate affects zinc absorption from the gastrointestinal tract through complexation and precipitation. As phytate cannot be digested or absorbed, the zinc bound to phytate will also pass through the intestine unabsorbed. Thus, people who depend on plant-based diets such as in many developing countries, face the risk of zinc deficiency due interference of phytate with zinc absorption. While high-fiber containing foods tend to be phytate-rich, fibre itself may not have a major effect on zinc absorption.

The amount and sources of protein influence its effect on zinc absorption. As protein content increases in a meal, a greater percentage of zinc is absorbed. Zinc absorption from a diet high in animal proteins (beef, eggs and cheese) is greater than from a diet high in plant proteins such as soy and legume. Other protein sources such as casein (milk protein) have an inhibitory effect on zinc absorption while soy protein did not appear to significantly inhibit zinc absorption.

Excess dietary calcium has been shown to decrease zinc absorption in animals, but such an effect is less conclusive in humans. While calcium phosphate decreases zinc absorption, calcium citrate-malate does not. The presence of phytate may also influence the effect of calcium on zinc absorption. Calcium may interact with zinc and phytate to form insoluble complexes, thus rendering zinc unavailable. Nonetheless, present data suggests that a calcium-rich diet has no significant inhibitory effect on zinc absorption, provided intake of zinc is adequate.

Several other factors may also be important. The amount of zinc in a meal will affect zinc absorption in that as the zinc amount in a meal increases, the fractional zinc absorption will decrease. Also, low zinc diets will increase zinc absorption and retention. Increasing dietary intake of phosphorous will increase markedly zinc requirement. Dietary sources of phosphorous include phytate and phosphorous-rich proteins (milk casein), which can bind zinc and decrease zinc absorption. High iron concentrations that are present in some supplements can reduce zinc absorption. The effect of iron on zinc will only occur when iron to zinc ratio is very high (e.g. 25:1) and both are administered in solutions. However, no such effect occurs when iron and zinc were given with a meal and administered in a supplement. Similarly, iron fortification of foods has no adverse effect on zinc absorption and long term use of iron supplements does not impair zinc absorption or status. Thus, Zn-Fe interaction may not likely have a major influence on zinc requirement under most dietary conditions. The interaction between copper and zinc have has been observed mostly in animals with no consistent adverse effect of copper intake on zinc absorption and utilization. Studies on zinc-folate interaction have produced conflicting results in that some have shown low zinc intake decreases folate absorption, while others have not found such an adverse effect. Folate supplementation also does not appear to have a deleterious effect on zinc status.

17.5 Setting requirements and recommended intake of zinc

General considerations

The Malaysian RDI (Teoh, 1975) has not made recommendations for zinc intake. Due to the importance of zinc nutriture in human health and disease, the revised Malaysian Recommended Nutrient Intake (RNI) will include zinc in its recommendations. For this purpose, the recommended zinc values for Malaysian population are based essentially on the zinc intake recommendations of FAO/WHO (2002). The discussion will also take into consideration the zinc intake recommendations by IZiNCG (2004) and IOM (2001).

The recommended level of nutrient intake, aimed at meeting the physiologic requirement of almost all (97.5%) individuals, is normally set at EAR + 2 SD (standard deviations), the EAR being the estimated average requirement that meets the physiologic requirements of 50% of the population. FAO/WHO (2002) assumed that the variation in dietary zinc requirements, which includes both the variation in requirement for absorbed zinc and variation in absorptive efficiency, corresponds to a coefficient variation (CV) of 25% (1 SD). The proposed RNI for Malaysia is set according to similar considerations.

The IOM (2001), IZiNCG (2004) and FAO/WHO (2002) reports used a factorial method for computing the EAR of zinc for most age and physiologic groups. The EAR of zinc is the amount of zinc that must be absorbed to match the amount of endogenous zinc losses. Both intestinal and non-intestinal sources (urine, surface losses of skin/hair/nail/sweat) contribute to endogenous zinc losses. The estimated physiological requirements for absorbed zinc in adult men and women are estimated to be 1.4 mg/day and 1.0 mg/day, respectively by FAO/WHO (2002) (Table 17.2). The estimations made by IOM (2001) and IZiNCG (2004) are also tabulated for comparison. Extrapolations from these values are done to estimate endogenous losses in children (6 months to 18 years). In these growing age groups, the rate of accretion and zinc content of newly formed tissues are also included in the estimation of their physiologic requirements. As for pregnancy and lactation, zinc retention during pregnancy and zinc concentration in human milk at different stages are also added to the requirement estimations.

The estimation of physiologic zinc requirement also requires reference body weights for various age groups. FAO/WHO (2002) and IZiNCG (2004) have utilized the NCHS/CDC 1977 growth reference which is more applicable to the international populations (Table 17.2). IOM (2001), on the other hand applied reference body weights which represented those of North American populations. For the Malaysian RNI, the reference body weights of Malaysians are utilised for all age groups.

Table 17.3 summarises the dietary zinc absorption estimates used by the FAO/WHO consultation, the IOM DRI Committee and IZiNCG consultation. The translation of estimates of absorbed zinc to dietary zinc requirement by FAO/WHO (2002) involved two considerations. First, the content of promoters and inhibitors of zinc absorption in the diet determines the fraction of dietary zinc that is potentially absorbable. Second, the efficiency of absorption of potentially available zinc is inversely related to zinc content in the diet. Based on these considerations and other data from zinc absorption studies, three categories of diets (high, moderate and low zinc bio-availability) with their respective fractional absorption rates (50%, 30% and 15%) were identified. For categorizing diets according to their potential bioavailability of zinc, the following criteria were used:

(i). High zinc bioavailability
The diet consists of refined foods low in cereal fibre, phytic acid content and phytate-zinc molar ratio < 5; has non-plant sources of zinc such as meats, fish, certain seafood and poultry.

(ii). Moderate zinc bioavailability
Mixed diet with animal or fish protein; lacto-ovo, ovovegetarian or vegan diets not based primarily on unrefined cereals or high-extraction-rate flours; the range of phytate-zinc molar ratio is 5-15 or not exceeding 10 if more than 50% of the energy intake is from unfermented, unrefined cereals and flours.

Table 17.2 Estimated physiological requirements for absorbed zinc in adult men and women by FAO/WHO (2002), IOM (2001) and IZiNCG (2004)

Endogenous zinc losses by source of loss (mg/day)	FAO/WHO	IOM	IZiNCG
Men			
Reference body weight (kg)	65	75	65
Urinary excretion	0.30	0.63	0.63
Integument	0.30	0.54	0.42
Semen	-	0.10	0.10
Total non-intestinal endogenous losses	0.60	1.27	1.15
Intestinal excretion of endogenous zinc	0.80	2.57	1.54
Total endogenous losses	**1.40**	**3.84**	**2.69**
Women			
Reference body weight (kg)	55	65	55
Urinary excretion	0.30	0.44	0.44
Integument	0.20	0.46	0.36
Menstrual blood	-	0.10	0
Total non-intestinal endogenous losses	0.50	1.00	0.80
Intestinal excretion of endogenous zinc	0.50	2.30	1.06
Total endogenous losses	**1.00**	**3.30**	**1.86**
Additional requirements for pregnancy (1st – 3rd trimesters)	0.1, 0.3, 0.7	0.16, 0.39, 0.63	0.70 [a]
Additional requirements for lactation (0-3 mth, 3-6 months, > 6 months)	1.4, 0.8, 0.5	1.35 [b]	1.0 [b]

[a] A single estimate for additional zinc requirements is applied throughout pregnancy
[b] A single estimate for additional zinc requirements is applied throughout lactation
Source: IZiNCG (2004)

(iii). Low zinc bioavailability
The diet consists of high unrefined, unfermented and ungerminated cereals with fortification of inorganic calcium salts (> 1 g Ca^{2+} / day) and negligible intake of animal food sources; the diet includes high-phytate soy-protein, cereal (wheat, rice, maize, oatmeal, millet), legume and lentil products.

The Technical Sub-Committee (TSC) on Minerals was of the opinion that the general diet of the Malaysian population is closer to that described for moderate zinc bioavailability. The TSC therefore recommended to adopt the FAO/WHO (2002) zinc values of diet with zinc absorption of 30%.

Table 17.3 Estimated dietary zinc absorption by FAO/WHO (2002), IOM (2001) and IZiNCG (2004)

	FAO/WHO			IOM	IZiNCG	
Diet types represented	**Highly refined** [a]	**Mixed/, Refined vegetarian** [b]	**Unrefined** [c]	**Mixed; semi-purified; EDTA-washed soy protein**	**Mixed, Refined vegetarian**	**Unrefined, cereal-based**
Study type	Single meal and total diet			Total diet	Total diet	
Subjects	NA [d]	NA	NA	Men 19-50 Years	Men and women 20+ years	
Phytate: zinc molar ratio	< 5	5 – 15	> 15	NA	4 – 18	> 18
Zinc absorption [e]	50%	30%	15%	41%	26% M 34% F	18% M 25% F

[a] Refined diets low in cereal fibre and animal foods provide the principle source of protein. Includes semi-purified formula diets

[b] Mixed diets and lacto-ovo-vegetarian diets that are not based on unrefined cereal grains or high extraction rate (> 90%) flours.

[c] Cereal-based diets with > 50% of energy intake from unrefined cereal grains or legumes and negligible animal protein intake.

[d] NA=not available

[e] Critical level of zinc absorption or level of zinc intakes are just sufficient to meet physiologic requirements for absorbed zinc

Source: IZiNCG (2004)

Recommended intakes by age groups

Upon reviewing available information, the Technical Sub-Committee on Minerals has proposed the RNIs for zinc for Malaysia are given in bold in the following paragraphs according to age groups and summarised in Appendix 17.1.

Infants (0 – 5 months)

No functional criteria of zinc status have been demonstrated that reflect reponse to dietary intake in infants. Thus, the recommended intakes of zinc were based on observed mean zinc intake of infants exclusively fed human milk. The IOM based its adequate intake (AI) on the average amount of zinc transfer in breast milk from 0-5 months post-partum. Thus, an AI of 2.0 mg/day (2.5 mg/l x 0.78 l/day) is proposed for infants in this age group. IZiNCG (2004) concluded that the amount of zinc from breast milk is adequate for the exclusively breastfed, normal birth-weight term infants up to 6 months of age. Consequently, IZiNCG set the AI of zinc from breast milk as 1.64 mg/day (2.3 mg/l x 0.714 l/day) for 0-2 months and 1.06 mg/day (1.35 mg/l x 0.784 L/day) for 3-5 months.

Meanwhile, FAO/WHO (2002) estimated the physiologic requirement of this age group by extrapolating from metabolic rate data for adults and adding the zinc content in newly deposited tissues. In human-milk fed infants, the endogenous zinc losses were assumed to be 20 µg/kg/day while that of infants fed formula or weaning foods was 40 µg/kg/day. For infant growth, estimated zinc increases were set at 120 and 140 µg/kg/day for female and male infants respectively for the first 3 months. The recommended zinc intakes are based on the sources of milk assuming that human milk has the highest zinc bioavailability followed by a mix of whey adjusted milk formula and partly human-milk or low-phytate food supplements with other liquid milks (moderate bioavailability) and phytate-rich vegetable protein based formula (soy) with or without whole grain cereals (low bioavailability).

For the Malaysian RNI, the TSC on Minerals recommends zinc intakes to be based on sources of milk with the highest (human milk) and moderate (infant formula) bioavailability levels.

RNI for infants

0 – 5 months	**breast fed**	**1.1 mg/day**
	formula fed	**2.8 mg/day**

Infants (6 – 11 months)

In order to obtain the estimated average requirement (EAR) for infants of 6-11 months of age, IOM (2001) and IZiNCG (2004) have utilized the same fractional zinc absorption from human milk as 50%. The amount of absorbed zinc required from complementary foods is determined as a difference between the required absorbed zinc and the amount of zinc ingested from the milk. The EAR for infants (breastfed and non-breastfed) is then calculated as the amount of zinc from human milk plus the amount of zinc from complementary foods, assuming fractional absorption of zinc is 30% from complementary foods. By 7 and 12 months of age, human milk provides only 0.5 mg zinc/day and 0.39 mg zinc/day, respectively. The NHANES III data indicated that the median zinc intake from complementary foods is 1.48 mg/day for older infants consuming human milk.

Meanwhile, FAO/WHO (2002) estimated the physiologic zinc requirement for this age group based on extrapolations from the data used to estimate the endogenous zinc losses in adults. Thus, an average loss of 0.57 µg/basal kcal was derived for this age group. The estimated zinc increase for this age group was set at 33 µg/kg/day. Different physiologic requirements (µg/kg body weight/day) were set for different levels of zinc bioavailability.

For the Malaysian RNI, assuming that infants in this age group are already supplemented with diets of moderate zinc bioavailability, the TSC on Minerals has set the physiologic requirement for zinc at 0.311 mg/kg body weight/day as recommended by FAO/WHO (2002). Thus, based on the reference body weight of 8 kg for this age group, the recommended nutrient intake is 3.7 mg/day.

RNI for infants

6 – 11 months	**3.7 mg/day**

Children and adolescents

IOM (2001) and IZiNCG (2004) calculated the endogenous zinc losses and amount of zinc required for growth for children in this age group as 0.034 mg/kg body weight/day and 0.020 mg/g of tissue gained respectively. An additional 0.1 mg/day was included in the estimated physiologic requirements for male adolescents 14-18 years to account for zinc losses in the semen. These values for endogenous losses and zinc required for growth are then multiplied respectively by the reference body weight and the expected rate of weight gain for the respective age groups.

The FAO/WHO (2002) meanwhile estimated the physiologic zinc requirement in this age group by extrapolating from estimations on endogenous losses in adults. Similar to infants 6-11 months, an average loss of 0.57 µg/basal kcal was utilized. For 1-10 years of age, growth requirements were based on the assumption that new tissue contains 30 µg/g (0.030 mg/g) zinc. During adolescence, a zinc content of 23 µg/g (0.023 mg/g) increase in body weight was assumed. The FAO/WHO consultation did not include zinc loss in semen.

Different physiologic requirements (µg/kg body weight/day) were set for different levels of zinc bioavailability. Assuming Malaysian diets to have moderate zinc bioavailability, the TSC on Minerals estimated the physiologic requirements for zinc (mg/kg body weight/day) for the various age groups to be as follows: 1-3 years, 0.230; 4-6 years, 0.190; 7-9 years, 0.149; 10-18 years (M), 0.133; and 10-18 years (F), 0.113. Using these age-specific physiologic requirements and the reference body weights of Malaysian children, the Malaysian RNIs of zinc for 1-18 years are as below:

RNI for children

1 - 3 years	**4.1 mg/day**
4 - 6 years	**5.1 mg/day**
7 - 9 years	**5.8 mg/day**

RNI for adolescents

Boys	**10 – 18 years**	**9.0 mg/day**
Girls	**10 – 18 years**	**7.5 mg/day**

Adults

The comparisons of estimated physiological requirements for absorbed zinc in adult men and women by FAO/WHO (2002), IOM (2001) and IZiNCG (2004) were previously shown in Table 17.2. Total endogenous losses for men and women differed among the three committees with the values set by IZiNCG (M – 2.69 mg/day; F – 1.86 mg/day) intermediate to the low values proposed by FAO/WHO (M – 1.4 mg/day; F – 1.0mg/day) and the high levels of IOM (M – 3.84 mg/day; F – 3.30 mg/day). For most estimations of intestinal and non-intestinal endogenous zinc losses, IZiNCG (2004) and IOM utilized a similar conceptual approach. For example, while FAO/WHO (2002) did not include zinc loss in semen and estimated intestinal loss of endogenous zinc based on the results from one study, IZiNCG (2004) and IOM (2001) included zinc loss in semen and reviewed a larger number of studies to estimate intestinal loss of endogenous zinc. The differences in the calculation of total endogenous losses for men and women by these committees resulted in different estimates of average requirement for zinc and the consequent recommended intake of zinc.

The requirements for the elderly are estimated in the same way as those for other adults. A higher requirement may be necessary for the elderly due to lower efficiency of zinc absorption. On the other hand, endogenous losses seem to be lower in the elderly. Hence, the FAO/WHO consultation had recommended the same intakes for the elderly and the other adults.

The TSC on Minerals recommended that the Malaysian RNI of zinc for men and women be based on the approach of FAO/WHO (2002) and the physiologic requirements for diets with moderate zinc bioavailability, namely:

Men	0.072 mg/kg body weight/day
Women	0.059 mg/kg body weight/day

Thus, using reference body weights of 62 kg and 55 kg for adult Malaysian men and women (19-65 years) and 57 kg and 49 kg for older men and women (65+ years) respectively, the Malaysian RNI of zinc for men and women are as given below. As recommended by the FAO/WHO Consultation, the same intake is recommended for the elderly. The slightly lower figure given below for the elderly is because of the slightly lower mean body weight of this group compared with the other adults.

RNI for adults

Men	**19-65 years**	**6.7 mg/day**
Women	**19-65 years**	**4.9 mg/day**

RNI for elderly

Men	**> 65 years**	**6.2 mg/day**
Women	**> 65 years**	**4.3 mg/day**

Pregnancy and Lactation

Physiologic zinc requirement increases during pregnancy due to accrual of fetal and maternal tissues. For this purpose, IOM (2001) estimated additional zinc requirements of 0.16 mg/day for the first trimester, 0.39 mg/day for the second trimester and 0.63 mg/day for third trimester. FAO/WHO (2002) provided estimates of 0.10 mg/day for first trimester, 0.30 mg/day for second trimester and 0.70 mg/day for third trimester. IZiNCG (2004) proposed 0.7 mg/day as additional zinc requirement for all trimesters of pregnancy which may overestimate the average requirements for absorbed zinc in the first and second trimesters. This amount should be added to the age-specific requirement for absorbed zinc of adolescents or adult women (Table 17.2).

Zinc requirements for lactating women vary according to the zinc content of human milk and the amount of milk produced during the first and second half of the year. Thus, the amount of zinc transferred from mother to infant in human milk must be added to the physiologic requirement for absorbed zinc in lactating women. IOM (2001) proposed an estimate of 1.35 mg/day as an average additional amount of absorbed zinc required for lactation, after discounting approximately 1 mg/day of endogenous zinc (accumulated during pregnancy) for the first month of postpartum. Using a similar approach as IOM (2001), IZiNCG (2004) proposed an additional amount of absorbed zinc as 1.0 mg/day throughout lactation based on the age-specific average milk volume transferred to the infants and the zinc concentrations in human milk. This amount should be added to the age-specific requirement for absorbed zinc of adolescents or adult women.

FAO/WHO (2002) estimated zinc concentrations in human milk as 2 – 3 mg/l at 1 month, 0.9 mg/l at 3 months and 0.7 mg/l at 4 months. Based on this, the Consultation estimated the average additional zinc amounts during the first year of post partum as 1.4 mg/day (0-3 months), 0.8 mg/day (3-6 months) and 0.5 mg/day (> 6 months) (Table 17.2).

The TSC on Minerals decided to adopt the additional amounts of zinc recommended by FAO/WHO (2002) for pregnancy and lactation. The proposed Malaysian RNI of zinc, based on diets of moderate zinc bioavailability is as follows.

RNI for pregnancy	
1st trimester	**5.5 mg/day**
2nd trimester	**7.0 mg/day**
3rd trimester	**10.0 mg/day**
RNI for lactation	
0 - 3 months	**9.5 mg/day**
4 - 6 months	**8.8 mg/day**
7 - 12 months	**7.2 mg/day**

Discussions on revised RNI for Malaysia

The inclusion of zinc into the revised RNI for Malaysia is justified due to its important role in human health and nutrition. The different approaches in estimating physiologic zinc requirement and dietary zinc absorption among FAO/WHO (2002), IOM (2001) and IZiNCG (2004) resulted in similar recommended zinc values by IOM and IZiNCG, which are somewhat different from those recommended by FAO/WHO (Appendix 17.1). From birth until early adolescence, the recommended zinc values set by IOM and IZiNCG tend to lie between the moderate to high zinc bioavailability values of FAO/WHO. During adolescence, adulthood, pregnancy and lactation, the values of IOM and IZiNCG are between the low to moderate zinc bioavailability values of FAO/WHO. The Malaysian RNI is based on the approach by FAO/WHO for diets with moderate zinc bioavailability but adjusted according to the local reference body weights. It is noted that for the same age groups (10-18 years, male and female) and > 19 years (male), the RNI values are lower than those in FAO/WHO due to the lower reference body weights of Malaysians.

17.6 Toxicity and tolerable upper intake levels

Excessive zinc intakes can produce acute and chronic effects of toxicity. No evidence of adverse effects of intakes of naturally occurring zinc in food has been reported. These deleterious toxic effects occur mostly via over-supplementation with zinc. Acute effects of zinc toxicity (200 mg zinc or more) can produce metallic taste, gastric distress, dizziness, vomiting, nausea, abdominal cramps and bloody diarrhea. Chronic effects (100-300 mg zinc daily) in adults can result in reduction of immune functions and HDL cholesterol and impairment of copper status (Fosmire, 1990).

Table 17.4 presents the tolerable upper intake levels for zinc intake proposed by IOM (2001). FAO/WHO (2002) set the upper level of zinc intake for an adult man at 45 mg/day. This level was then extrapolated to other groups in relation to basal metabolic rate. For children, this resulted in an upper limit of intake of 23-28 mg/day.

Table 17.4 Tolerable Upper Intake Level (UL) for zinc according to age groups

Age groups	mg/day of zinc
Infants	
0-6 months	4
7-12 months	5
Children	
1-3 years	7
4-8 years	12
9-13 years	23
Adolescents 14 – 18 years	34
Adult women ≥19 years	40
Adult men ≥ 19 years	40
Pregnant women	
14-18 years	34
19-50 years	40
Lactation women	
14-18 years	34
19-50 years	40

(Source: IOM, 2001)

17.7 Research recommendations

The following priority areas of research are recommended:

- Assessment of dietary zinc intakes and status of population groups such as children, elderly, pregnant and lactating women who may be at risk of zinc deficiency

- Examine the association between zinc intakes, status and possible outcomes of zinc deficiency (e.g. growth retardation, impaired immune status, pregnancy outcomes).
- Determination of zinc content and bioavailability of typical mixed diets of various ethnic and socioeconomic groups in the country
- Research on the effects of zinc supplementations in specific population groups e.g. low birth weight infants, young children, pregnant women and elderly.

17.8 References

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Appendix 17.1 Comparison of recommended intake for zinc: RNI Malaysia (2005), RNI of FAO/WHO (2002), RDA of IOM (2001) and IZiNCG (2004)

Malaysia (2005)		FAO/WHO (2002)				IOM (2001)		IZiNCG (2004)		
Age groups	RNI (mg/day)	Age groups	RNI (mg/day)			Age groups	AI (mg/day)	Age groups	AI (mg/day)	
	Moderate bio-availability		High bio-availability	Moderate bio-availability	Low bio-availability					
Infants		Infants				Infants		Infants		
0 – 5 months	1.1 (bf) 2.8 (ff)	0 – 5 months	1.1 (bf)	2.8 (ff)	6.6 (ff)	0 – 6 months	2.0	0 – 2 months	1.64	
6 – 11 months	3.7	6 – 11 months	0.8 (ff) 2.5 *	4.1	8.3			3 – 5 months	1.06	
							RDA (mg/day)		RDA (mg/day) Mixed or refined vegetarian diets	Unrefined, cereal-based diets
						7 – 12 months	3.0	6 – 11 months	4.0	5.0
Children		Children				Children		Children		
1 – 3 years	4.1	1 – 3 years	2.4	4.1	8.4	1 – 3 years	3.0	1 – 3 years	3.0	3.0
4 – 6 years	5.1	4 – 6 years	3.1	5.1	10.3	4 – 8 years	5.0	4 – 8 years	4.0	5.0
7 – 9 years	5.8	7 – 9 years	3.3	5.6	11.3			9 – 13 years	6.0	9.0
Boys		Boys				Boys		Boys		
10 – 18 years	9.0	10 – 18 years	5.7	9.7	19.2	9 – 13 years	8.0	14 – 18 years	10.0	14.0
						14 – 18 years	11.0			
Girls		Girls				Girls		Girls		
10 – 18 years	7.5	10 – 18 years	4.6	7.8	15.5	9 – 13 years	8.0	14 – 18 years	9.0	11.0
						14 – 18 years	9.0			
Men		Men				Men		Men		
19 – 65 years	6.7	19 – 65 years	4.2	7.0	14.0	19 – 30 years	11.0	> 19 years	13.0	19.0
> 65 years	6.2	>65 years	4.2	7.0	14.0	31 – 50 years	11.0			
						51 – 70 years				
						> 70years				
Women		Women				Women		Women		
19 – 65 years	4.9	19 – 65 years	3.0	4.9	9.8	19 – 30 years	8.0	> 19 years	8.0	9.0
> 65years	4.3	>65 years	3.0	4.9	9.8	31 – 50 years	8.0			
						51 – 70 years	8.0			
						> 70 years	8.0			
Pregnancy		Pregnancy				Pregnancy**		Pregnancy		
1st trimester	5.5	1st trimester	3.4	5.5	11.0	14 – 18 years	12.0	14 – 18 years	11.0	15.0
2nd trimester	7.0	2nd trimester	4.2	7.0	14.0	19 – 30 years	11.0	> 19 years	10.0	13.0
3rd trimester	10.0	3rd trimester	6.0	10.0	20.0	31 – 50 years	11.0			
Lactation		Lactation				Lactation***		Lactation		
0 – 3 months	9.5	0 – 3 months	5.8	9.5	19.0	14 – 18 years	13.0	14 – 18 years	10.0	11.0
4 – 6 months	8.8	4 – 6 months	5.3	8.8	17.5	19 – 30 years	12.0	> 19 years	9.0	10.0
7 – 12 months	7.2	7 – 12 months	4.3	7.2	14.4	31 – 50 years	12.0			

bf=breast fed ff=formula fed

* not applicable to infants consuming human milk only

** throughout the 1st, 2nd and 3rd trimesters

*** throughout the first year of post-partum