Original Article

Iron status and dietary iron intake of adolescents from a rural community in Sabah, Malaysia

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Iron deficiency anaemia (IDA) is the most prevalent micronutrient deficiency in the world affecting the general health and wellbeing of millions. In Malaysia, moderately high prevalences of anaemia have been reported amongst infants, young children and women of childbearing age. Data is scant for the adolescents. This study was undertaken to assess the iron status and dietary intake of 165 adolescents, comprising 74 male and 91 female subjects, aged 12 to 19 years, from the rural communities in Tuaran District of Sabah, Malaysia. Convenience sampling was used for the selection of study subjects. Multiple iron status indicators namely, serum ferritin (SF), transferrin saturation (TS), mean corpuscular volume (MCV) and haemoglobin (Hb) were determined for the study. The mean age of the subjects was 15.2 ± 2.1 years. While the majority of the subjects (77.6%) had normal body mass index (BMI) values, 17.6% were underweight and 4.8% overweight. About 35% to 40% of the subjects showed deficient values for haematocrit, serum ferritin, serum iron, mean corpuscular haemoglobin (MCH), mean corpuscular volume (MCV) and transferrin saturation (TS), and 20% were anaemic (Hb <12 g/L). Using the multiple criteria of iron status indicators, the prevalence of iron depletion, iron deficiency and IDA in the male and female adolescents were 5.4% vs. 6.6%, 18.9% vs. 26.4% and 5.4% vs. 26.4%, respectively. Iron deficiency anaemia (85.0%) contributed largely to the prevalence of anaemia. The dietary iron intake of the adolescents was unsatisfactory, with approximately 98% of subjects failing to meet the Malaysian RDA level. Almost all the female subjects (91%) had dietary iron intake below two-thirds of the RDA level compared with a much smaller proportion for the male adolescents (68%). The prevalence of IDA in the present study population, especially in the female adolescents, appears to be a significant public health problem. Priority should therefore be given to the eradication of iron deficiency in adolescents from low-income areas by dietary modification and micronutrient supplementation amongst female adolescents.

Key Words: iron status, dietary iron intake, iron deficiency anaemia (IDA), female adolescents, Sabah, Malaysia.

Introduction

Iron deficiency is a major nutritional deficiency in both industrialized countries[1,2] and developing countries,[3,4] including Malaysia.[5,6] The prevalence of anaemia in developing countries is three to four times higher than that in industrialized countries. More than 3.5 billion people in the developing countries are estimated to suffer from anaemia.[4] In fact, the estimated prevalence of iron deficiency worldwide is high, affecting the general health and well-being of 2000 million people. Serious consequences of anaemia have been shown in several studies and include impaired cognitive function, optimal behaviour,[7] and reduced immune function leading to increased risk of morbidity and mortality.[8] Anaemia also has deleterious effects on school academic performance,[9] general health and well-being, reproductive performance,[8] physical performance[10] and work capacity.[11] In Malaysia, iron deficiency anaemia has been reported as one of the most important micronutrient deficiencies for the past several decades. Several nutritional anaemia surveys in the 1908s in the 1980s and 1990s highlighted the widespread problem of iron deficiency anaemia among infants, young children and pregnant women in Malaysia.[6,12-15] However, there is a dearth of data on anaemia among adolescents in Malaysia. In Sabah, data on nutritional anaemia is lacking; there are only two studies with respect to anaemia in children in the 1980s.[13,14] Information on iron deficiency anaemia is much needed as it has serious implications on the overall health of individuals, and for national, economic and social development.

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Adolescence is characterised by a large growth spurt and maturation. Rapid growth during adolescence renders positive iron balance difficult to maintain. This is due to the expansion of blood volume that occurs concurrently with growth.[16] It is also a period of increased overall iron requirement because of the adolescent spurt in body mass, and, in female adolescents, because of the onset of menstrual losses. Iron status during adolescence may be complicated further by low dietary iron intakes.[2] Thus, this study was formulated to assess the iron status and dietary intakes of adolescent boys and girls in rural fishing communities in Sabah, Malaysia. Multiple haematological and biochemical parameters were used to determine iron status in order to reflect changes to the stages of iron deficiency prevalence.

Materials and methods

Study design

Sabah is one of the thirteen states of Malaysia. Together with Sarawak, it is situated on the large island of Borneo to the east, separated from the Peninsular Malaysia. The study was carried out in six fishing village communities: Serusop, Penimbawan, Tajau, Kindu, Betutai and Sambah village in the Tuaran District of Sabah, Malaysia. All the villages were purposively selected because of the homogenous nature of the populations in these villages with respect to their ethnicity, socio-cultural and daily economic activities which was considered appropriate for the objective of this study.

Subjects

Male and female adolescents aged 12 to 19 years from all the selected fishing communities who had no history of any medical conditions or medications known to affect iron metabolism were invited to participate in the study. Out of 225 eligible adolescents, 18 mothers or guardians refused to give their consent, 5 adolescents refused to have blood taken and 3 adolescents had other reasons for non-participation. Thus, a total of 199 apparently healthy adolescents, comprising 94 males and 105 females, living in the fishing commu-nities in Tuaran, Sabah, Malaysia, who met the selection criteria, were invited to participate in this study. Anthro-pometric measurements and 3 days of 24-hour dietary recall were elicited from all the subjects. The results presented in this paper are only for those subjects who had blood drawn for iron status measure-ments (i.e 74 males and 91 females). About 20 males and 14 females refused to have blood drawn and/or were absent during blood collection. The study was approved by the State Health Department of Sabah and verbal and written consent was obtained from all adolescents and their parents.

Anthropometric measurement

Measurements of body weight and height, performed according to standard procedures[17], were taken on the day of blood collection. Body weight was measured with light clothing using an electronic digital scale (TANITA Corporation, Japan) with an accuracy of 0.1kg, calibrated with a 5kg calibrator daily. Height was taken using a microtoise tape (Seca bodymeter 208), calibrated for an error of measurement of 0.1cm. Shoes and socks were also removed before measurements were taken. A trained community nurse took all the measurements in order to minimize inter-observer variations of measurement. Anthropometric measurements were taken twice; when necessary any discrepancies were resolved by a third measurement. Mean average values were used for data analysis.

Haematological and biochemical measurements

A total of 5ml fasting venous blood was taken from each subject, of which 2ml was collected into EDTA-containing tubes for the analysis of full blood count, while the remaining 3ml was collected into an evacuated tube containing no anticoagulant for the analysis of serum ferritin, serum iron and total iron binding capacity (TIBC) concentrations. Haemoglobin and red cell indices were analyzed using an Abbott Cell-Dyne® 1700 (Abbott Diagnostics Division, U.S). Analyses of the full blood count were carried out within 4 hours after blood collection, as recommended by the International Committee for Standardization in Haematology (ICSH),[18,19] in the Luyang Polyclinic, Kota Kinabalu. Blood for biochemical determinations was allowed to clot at room temperature (25°C), after which the serum was obtained by centrifugation at 3000 x g for 15 min. The serum was separated and stored at –20°C for later determinations. Serum ferritin concentrations were measured with the use of a microparticle enzyme immunoassay (MEIA) procedure (Automated immunoassay IM_X system Analyzer-Abbott Diagnostics Division, U.S), whereas serum iron and TIBC were measured by a modification of the automated Technicon Ferene-S method (Technicon RA-XT system). These analyses were done within a month of blood collection in the Clinical Biochemistry Unit of the Pathology Department, Queen Elizabeth Hospital in Kota Kinabalu, Sabah. For quality control purposes, repeated measurements were carried out on the 15 haematological and biochemical tests for each blood sample. The within-day assay variations for Hb, MCV, serum ferritin, serum iron and TIBC, expressed as coefficient of variation (CV) were 0.6%, 0.7%, 4.0%, 4.7% and 5.5% respectively. The within-subject CV (%) was calculated as follows: σ_{within}/mean x 100

Nutrient intakes

Dietary intakes were assessed by using 24-hour dietary recalls for 3 days, comprising two weekdays and one weekend day. Subjects were asked to recall all the foods and beverages consumed the day before. Food models and household measurements were used to assist the subjects. Calories and nutrient intakes were calculated using the nutrient conversion computer programme "*Diet 4*" which is based on the Malaysian food composition table.[20] The Malaysian Recommended Daily Allowance (RDA)[21] for specific nutrients was also used to evaluate the nutrient adequacy of the subjects.

Blood malaria parasite examination

Anaemia is positively associated with the presence of malaria parasites.[22] The malaria parasite was detected by a Blood Smear for Malaria Parasites (BSMP). Thick and thin blood smears were fixed and stained with Giemsa

and examined for malaria parasites by Vector Control Technologist from District Health Office of Tuaran. A random 20% sub-sample of the slides were re-examined by an entomologist from the Vector Control Division of the State Health of Depart-ment of Sabah, as a quality control measure. Agreement between the entomologists was excellent for the absence of malaria parasitaemia. None of the subjects were positively diagnosed for the presence of malaria parasites.

Statistical analysis

All statistical analyses were performed by using the program Statistical Package for Social Sciences (SPSS® for windows version 9.0, SPSS Inc., Chicago, US). All variables were tested for normality by the Kolmogorov-Smirnov test and test of homogeneity of variance before any statistical comparisons were made. The results are presented either as the means and standard deviations (SD) or as proportions (%). The student's two-tailed independent sample t-test was performed to determine significant differences between gender for the various measurements and indices. Statistical significance for all the tests was defined at $P<0.05$. Classification of anthropometry and iron status parameters is as described in Table 1.

Results

General characteristic of subjects

A total of 165 adolescents consisting of 74 male and 91 female adolescents were included (Table 2). The mean (± SD) age of the adolescents was 15.2 ± 2.1 years, with the female subjects having a significantly higher mean age of 15.9 ± 2.2 years compared with their male counterparts (14.5 ± 1.7 years). Average year of schooling among the adolescents was 8.6 ± 1.9 years with the majority of the female (89%) and male subjects (77%) having received at least secondary education. The average household size of adolescents was 8.1 persons with almost half of them living in medium household sizes comprising 5 to 8 members per household. With regards to the socio-economic status of the subjects, almost three quarters of the households (73.3%) were earning below the poverty line, while 32.7% and 40.6% were categorised respectively as poor and hard-core poor.

Height and body weight

Mean height and body weight for the male and female subjects was 1.5 ± 0.1m, 1.5 ± 0.1m, 41.8 ± 10.8kg and 42.7 ± 7.1kg respectively. These values were not significantly different between the sexes. However, the female adolescents had a significantly higher mean body mass index (BMI) of 19.1 ± 2.7kg/m^2 than that for males (18.0 ± 3.2kg/m^2, P=0.016). Based on the BMI classification of the World Health Organization[17], 68.9% and 84.6% of the male and female subjects respectively were classified as normal (5th - 84.9th BMI percentile for age). About 17.6% of the adolescents were classified as thin (<5th percentile) with the males having a higher proportion of thin subjects (23%) than the female subjects (13.2%). A small proportion of the males (8.1%) and females (2.2%) were at risk of overweight (defined as BMI ≥85th value).

Biochemical and haematological profiles

The mean and standard deviation values of biochemical and haematological indicators of iron status are shown in Table 3. Medians and quartile values were also used for the serum ferritin and mean corpuscular volume (MCV), as their distributions were non-Gaussian.

Table 1. Classification of anthropometry and iron status parameters

Body weight and height measurements		
Body mass index (kg/m^2)[17]		
	< 5th percentile	Underweight
	5th – 84.9th percentile	Normal range
	≥ 85th percentile	At risk of overweight
Cut off limits used for iron status indiators[23-25]		
	Male	*Female*
Serum ferrintin	SF <12µg/L	SF <12µg/L
TS	TS<16%	TS<16%
MCV	MCV<78fl (11-14 years) MCV<80fl (≥15 years)	MCV<78fl (11-14 years) MCV<80fl (≥15 years)
Haemoglobin	Hb<12g/L (6-14 years) Hb<13g/L (≥15 years)	Hb <12g/L
Serum Iron	<10.74 µmol/L	<10.74 µmol/L
TIBC	>73.39 µmol/L	>73.39 µmol/L
Iron status indicators		
Iron status Classification		
Iron depletion	SF <12µg/L	
Iron deficiency	Hb>12g/L, plus two of the following three criteria (SF<12µg/L; TS<16%; MCV<78fl (11-14 years) or	MCV<80fl (≥15 years)
Iron deficiency anaemia (IDA)	Hb<12g/L, plus two of the following three criteria (SF<12µg/L; TS<16%; MCV<78fl (11-14 years) or MCV<80fl (≥15 years)	

Hb, Haemoglobin; SF, Serum ferritin; TS, Transferrin saturation; MCV, Mean corpuscular volume; TIBC, Total iron binding capacity

Table 2. General Characteristics of male and female subjects (*N* =165)

	Male (*N* = 74)	Female (*N* = 91)	Sexes combined (*N* = 165)
		% (No)	
Age (year)	(14.5 ± 1.7)[a]	(15.9 ± 2.2)[b]***	(15.2 ± 2.1)
12 – 15 years	71.6 (53)	41.8 (38)	55.2 (91)
16 – 19 years	28.4 (21)	58.2 (53)	44.8 (74)
Educational attainment (year)	(8.0 ± 1.9)	(9.1 ± 1.8)[b]***	(8.6 ± 1.9)
Up to primary school	23.0 (17)	11.0 (10)	16.4 (27)
Secondary school and above	77.0 (54)	89.0 (81)	83.6 (138)
Household size	(8.3 ± 2.7)	(7.8 ± 2.8)	(8.1 ± 2.7)
Small (1 – 4 persons)	9.5 (7)	11.0 (10)	10.3 (17)
Medium (5 – 8 persons)	41.9 (31)	54.9 (50)	49.1 (81)
Large (≥ 9 persons)	48.6 (36)	34.1 (31)	40.6 (67)
Monthly household income per capita	91.8 ± 55.6	101.2 ± 79.0	97.0 ± 69.0
≤ RM61[c] (Hard-core poor)	33.8 (25)	46.2 (42)	40.6 (67)
RM62 – RM123 (Poor)	41.9 (31)	25.3 (23)	32.7 (54)
RM124 – RM185	16.2 (12)	15.4 (14)	15.8 (26)
≥ RM186	8.1 (6)	13.2 (12)	10.9 (18)
Anthropometric parameters			
Body weight (kg)	(41.8 ± 10.8)	(42.7 ± 7.1)	(42.3 ± 8.9)
Height (m)	(1.5 ± 0.1)	(1.5 ± 0.1)	(1.5 ± 0.1)
Body mass index (kg/m^2)	(18.0 ± 3.2)	(19.1 ± 2.7)[b]*	(18.6 ± 3.0)
Thinness (< 5th percentile)	23.0 (17)	13.2 (12)	17.6 (29)
Normal (5th – 84.9th percentile)	68.9 (51)	84.6 (77)	77.6 (128)
At risk of overweight (≥85th percentile)	8.1 (6)	2.2 (2)	4.8 (8)

[a]Mean ± SD in parentheses; [b]significant difference between the gender at *P<0.05 and ***P<0.001 [c]RM1.00 = USD 0.26

Table 3. Biochemical and hematological parameters of the male and female adolescents (*N*=165)

Indicators	Male (*N*=74)		Female (*N* =91)		Sexes combined (*N* =165)	
	Mean ± SD	No (%) Deficient[a]	Mean ± SD	No (%) Deficient	Mean ± SD	No (%) deficient
Haemoglobin (Hb) (g/dl)	13.9 ± 1.3***	7 (9.5)	12.4 ± 1.6	26 (28.6)	13.1 ± 1.7	33 (20.0)
Haematocrit	40.6 ± 3.4***	31 (41.9)	36.4 ± 4.2	35 (38.5)	38.3 ± 4.4	66 (40.0)
Red blood count (RBC) (x 10^{-3}/mm^3)	5.1 ± 0.4***	7 (9.5)	4.7 ± 0.4	12 (13.2)	4.8 ± 0.5	19 (11.5)
Mean corpuscular volume[b] (MCV) (fl)	80.6 (42.1; 92.4)[c]	24 (32.4)	81.4 (46.8; 90.7)	38 (41.8)	81.0 (42.1; 92.4)	62 (37.6)
Mean corpuscular haemoglobin (MCH)(pg)	27.6 ± 2.2	25 (33.8)	26.7 ± 3.8	39 (42.9)	27.1 ± 3.2	64 (38.8)
Mean corpuscular haemoglobin conc (g/dl)	342.9 ± 12.3	3 (4.1)	339.6 ± 12.5	7 (7.7)	341.1 ± 12.5	10 (6.1)
Serum iron (SI) (µmol/L)	14.4 ± 5.9***	18 (24.3)	10.3 ± 5.6	47 (51.6)	12.1 ± 6.1	65 (39.4)
Total iron binding capacity(TIBC) µmol/L)	63.0 ± 14.3**	12 (16.2)	68.8 ± 13.2	33 (36.3)	66.2 ± 14.0	45 (27.3)
Transferrin saturation (TS) (%)	24.6 ± 14.4***	12 (16.2)	15.9 ± 9.5	46 (50.5)	19.8 ± 12.7	58 (35.2)
Serum ferritin[b] (SF) (µg/L)	21.5 (3.8; 177.5)*** (22.3 ± 26.2)[d]	19 (25.7)	15.4 (1.6; 43.2) (15.5 ± 21.3)	45 (49.5)	18.2 (1.6; 177.5) (16.9 ± 24.0)	64 (38.8)

[a]Criteria for deficient values are shown in Table 1; [b]analysis based on log-transformed data; [c]medians; 95% CI ranges in parentheses
[d]geometric mean ± SD in parentheses; significant difference between gender **P<0.01 and ***P<0.001; unpaired t-test

The mean values for serum ferritin, transferrin saturation, haemoglobin and MCV for the male and female subjects were 21.5μg/L vs 15.4μg/L, 24.6% vs 15.9%, 13.9g/dl vs 12.4g/dl and 80.6fl vs 81.4fl respectively. The serum ferritin and mean corpuscular volume (MCV), as their distributions were non-Gaussian. The mean The geometric mean serum ferritin value for both sexes combined was 16.9 ± 24.0μg/L, while the values for the male and female adolescents were 22.3 ± 26.2μg/L and 15.5 ± 21.3μg/L respectively. Approximately 35% to 40% of the subjects for the sexes combined showed deficient values for haematocrit (40%), serum ferritin (39%), serum iron (39%), mean corpuscular haemoglobin (MCH) (39%), mean corpuscular volume (38%) and transferrin saturation (35%). A small proportion (6%) had deficient mean corpuscular haemoglobin concentrations (MCHC). Males had significantly higher mean values in haemoglobin (P<0.001), haematocrit (P<0.001), red blood count (P<0.001), serum iron (P<0.001), transferrin saturation (TS) (P<0.001) and serum ferritin (P<0.001) than the female subjects. In contrast, female adolescents had a significantly higher level of total iron binding capacity (P<0.01) than their male counterparts.

Prevalence of iron deficiency anaemia

Prevalence of iron deficiency anaemia (IDA) among the adolescents (sexes combined) was 17.0% as shown in Table 4. About 23.3% and 20.0% were found with iron deficiency and anaemia respectively, while 6.1% showed iron depletion. Iron deficiency anaemia (85.0%) contributed largely to the prevalence of anaemia (92.3% of the females and 57.1% of the males). The prevalence of iron depletion, iron deficiency and iron deficiency anaemia among the male and female subjects were 5.4% vs 6.6%, 18.9% vs 26.4% and 5.4% vs 26.4% respectively.

Nutrient intakes

The intake of calories and all the nutrients studied, with the exception of vitamin A and riboflavin, were found to be normally distributed. The distributions for vitamin A and riboflavin intakes were normalized after transforming to $\log_{10}$. Intake of calories and nutrients of the male and female adolescents are presented in Table 5. Mean daily energy intake for the subjects was 1580 ± 268 kcal (6.6 ± 1.1 MJ) with the male subjects having a higher mean energy intake (1709 ± 231 kcal) than the female adolescents (1474 ± 249 kcal). Male adolescents had significantly higher intakes of energy, carbohydrates, protein, thiamine, niacin and ascorbic acid than their female counterparts. Sixty-six percent of the energy intake was derived from carbohydrates, 14% from protein and 20% from fat, all of which are within the recommendations of WHO.[26] The main sources of carbohydrates were rice, flour products and tubers. About 14% of energy was derived from protein, mainly from fish and seafood products.

Dietary iron intake

Mean daily iron intakes of the adolescents was 10.3 ± 2.8mg and there was no significant difference between the male and female subjects (Table 5). Iron intake was unsatisfactory, with almost all the subjects (98%) failing to meet the Malaysian RDA for iron (Table 6). Only 17.6% had intakes between two-thirds and 100% of the RDA. Iron intake among the female subjects was less adequate than that of the males. Almost all the female subjects (91.2%) had iron intakes below the two-third level of the RDA compared with 67.7% among the male adolescents. About three-quarters of the dietary iron of the adolescents was derived from foods of plant-origin such as rice and flour products (30%), nutrient-fortified beverages (14%), vegetables (10%), snacks (9%), cereals and tubers (9%), and fruits (5%). In contrast, only approximately 23% of the total iron intake was from animal-origin products namely, fish and seafood (12%), meat and chicken (6%) and eggs (5%). The male and female subjects showed a rather similar pattern for the sources of dietary iron.

Discussion

The majority of the male and female adolescents had body mass indices within the normal range. There were more underweight subjects than those at risk of overweight (23% vs 13% and 8% vs 2% respectively for the male and female subjects). Approximately 28.6% and 9.5% respectively of the female and male adolescents were anaemic, based on deficient values of haemoglobin concentrations. These levels were lower than that reported among adolescents aged 13 – 18 years in fishing villages in Peninsular Malaysia (42.7% for female and 48.1% for

Table 4. Classification of iron status among the male and female adolescents (N=165)

	Iron depletion[a]	Iron deficiency[b]	Anaemia[c]	Iron deficiency anaemia[d]	Anaemia due to iron deficiency anaemia, %
			% (N)		
Male (N= 74)	5.4 (4)	18.9 (14)	9.5 (7)	5.4 (4)	57.1
12 – 15 years (N=53)	7.5 (4)	17.0 (9)	7.5 (4)	5.7 (3)	75.0
16 – 19 years (N =21)	0	23.8 (5)	14.3 (3)	4.8 (1)	33.3
Female (N= 91)	6.6 (6)	26.4 (24)	28.6 (26)	26.4 (24)	92.3
12 – 15 years (N =38)	5.3 (2)	23.7 (9)	23.7 (9)	23.7 (9)	100.0
16 – 19 years (N =53)	7.5 (4)	28.3 (15)	32.1 (17)	28.3 (15)	88.2
Sexes combined (N= 165)	6.1 (10)	23.3 (38)	20.0 (33)	17.0 (28)	84.8

[a]Iron depletion is defined as serum ferritin<12 μg/L; [b]iron deficiency is defined as ≥2 abnormal values of 3 iron status indicators SF <12μg/L, TS <16% and MCV <74fl; [c]anaemia is defined as Hb <12g/dl; [d]iron deficiency anaemia is a combination of iron deficiency and Hb <12g/dl

Table 5. Mean daily nutrient intake of rural male and female adolescents aged 12 - 19 years (N = 165)

	Male (N = 74)	Female (N = 91)	Sexes combined (N = 165)
		Mean ± SD	
Energy (kcal)	1708.8 ± 231.3***	1474.3 ± 249.1	1579.5 ± 267.5
	(7.1 ± 1.0)[a]	(6.2 ± 0.1)	(6.6 ± 1.1)
Carbohydrate (g)	266.8 ± 14.6**	259.1 ± 17.2	262.6 ± 16.5
Protein (g)	59.9 ± 9.4***	53.9 ± 11.3	56.6 ± 10.9
Fat (g)	36.7 ± 8.2	34.1 ± 8.7	35.3 ± 8.5
% kcal carbohydrate[b]	66.7 ± 3.7	64.8 ± 4.3	65.6 ± 4.1
% kcal protein[b]	14.1 ± 1.6	14.7 ± 1.8	14.4 ± 1.8
% kcal fat[b]	19.2 ± 3.1	20.6 ± 3.5*	20.0 ± 3.4
Vitamin A[c] (μg RE)	543.4 ± 219.7	519.9 ± 176.9	530.5 ± 197.0
Thiamine (mg)	0.7 ± 0.2*	0.6 ± 0.2	0.6 ± 0.2
Riboflavin[c] (mg)	1.1 ± 0.3	1.0 ± 0.3	1.0 ± 0.3
Niacin (mg NE)	20.0 ± 3.7***	17.4 ± 3.8	18.6 ± 4.0
Ascorbic acid (mg)	83.8 ± 33.4*	71.8 ± 30.8	77.2 ± 32.5
Calcium (mg)	334.6 ± 109.2	320.0 ± 124.6	326.3 ± 117.8
Iron (mg)	10.6 ± 2.7	10.0 ± 2.9	10.3 ± 2.8

[a]Megajoule MJ ± SD in parentheses. [b]The amount of energy calculated by using the following conversion factors: Carbohydrate 4 kcal/g (17 kJ), Protein 4 kcal/g (17 kJ) and Fat 9 kcal/g (37 kJ). [c]Analyses were based on transformed data. Significant different between the gender at *P<0.05, **P<0.01 and ***P<0.001

Table 6. Percentage of male and female subjects with (i) iron intakes at various levels of adequacy based on Malaysia RDA[21] and (ii) sources of dietary iron contributed from food groups (N = 165)

	Male (N = 74)	Female (N = 91)	Sexes combined (N = 165)
		Percentage % (N)	
Iron intake based on RDA level	62.1[a]	42.6	51.3
≤66% RDA	67.6 (50)	91.2 (83)	80.6 (133)
67 – 100% RDA	29.7 (22)	7.7 (7)	17.6 (29)
>100% RDA	2.7 (2)	1.1 (1)	1.8 (3)
Dietary iron sources		Percentage %	
Plant-origin products	76.5	77.9	77.3
Rice and flour products	29.8	30.6	30.2
Nutrients fortified beverages[b]	11.3	15.9**	13.9
Vegetables	10.0	9.6	9.8
Snacks[c]	9.0	9.1	9.1
Cereals and tubers	10.3**	8.2	9.1
Fruits	6.1***	4.5	5.2
Animal-origin products	22.5	22.1	22.7
Fish and seafood	12.2	11.8	12.0
Chicken and meat	6.6*	5.7	6.1
Eggs	4.7	4.7	4.7

[a]Mean RDA. [b]Nutrients fortified beverages including Milo and full cream milk. [c]Snacks such as fried banana (pisang goreng) and typical local cakes. Significant different between gender at *P<0.05, **P<0.01 and ***P<0.001

male subjects).[6] However, the prevalence of anaemia (28.6%) amongst the females was higher than that reported by Tee *et al.*[5] for females aged 12 to 17 years in the Samarahan district, Sarawak. It is known that the physiological iron losses during menstrual bleeding increase body iron needs among females.[16,27] As a result this places a higher proportion of the female adolescents in the deficient range for the various iron status indicators compared with their male counterparts. The present findings are in general agreement with results from other studies which have also reported that female subjects have significantly lower iron status than the males.[3,27,28]

Since values of iron status indicators between normal and iron deficient individuals are known to overlap,[1,23,24] a combination of iron indicators was used in this study to improve the accuracy of detection of individuals with iron deficiency. The prevalence of iron deficiency anaemia among the subjects was 17%, with a higher prevalence among the females (26%) than males (5%).

The prevalence of iron deficiency anaemia in the present study appears to be higher than the levels reported in West Asia,[3] but lower for western countries, including United States,[1] United Kingdom[2] and Denmark.[29]

Data on the nutrient intake of Malaysian adolescents is lacking and it is particularly crucial because adolescence is a critical period during which lifetime habits are established. Many adolescents are preoccupied with their physical characteristics and appearance, resulting in undesirable dietary practices that may lead to inadequate intake of micronutrients resulting in iron deficiency anaemia.

Based on 3 days of 24-hour dietary recalls, consisting of two weekdays and a weekend day in order to reduce day-to-day variability of food consumption, the mean energy intake of the subjects was determined as 1580 ± 268 kcal (6.6 ± 1.1MJ). This is quite comparable with the mean energy intake (1511kcal) of a group of female adolescents aged 12-17 years in Sarawak.[5] It is higher

than the levels of energy intakes for 10-12 year old Malaysian urban adolescents (1520kcal and 1344kcal respectively for males and females).[30] However, the energy intake in this study is lower than that reported for ado-lescents in industrialized countries using different dietary assessment methods. In a study of Norwegian 18 year olds using the quantitative food frequency questionnaire, the mean intakes observed was 3776kcal (15.8MJ) for males and 2366kcal (9.9MJ) for females.[31] A 7-day die-tary record study among Swedish 15 year-olds reported mean intakes of 2414kcal (10.1MJ) for males and 1888kcal (7.9MJ) for females.[32]

The iron content of the diet is especially important in the adolescent period because of the need for growth and to replace losses.[28] The mean iron intakes of male and female adolescents in this study (10.7mg/d and 10.0mg/d respectively) are quite comparable with the findings of Poh *et al.,*[30] who reported mean iron intakes of 12.2mg among the males and 11.2mg for the female adolescents in Peninsular Malaysia. The mean level of iron intake among the Malaysian adolescents is poor, especially among the female subjects. Plant-based food sources contributed 77% of the total iron intake, which is similar to that reported among a group of adolescents in the Philippines (Kuizon *et al.,* 1982).[33] Such plant-based diets generally have low iron availability and can there-fore increase the risk of iron deficiency and anaemia.[34]

A matter of concern, in relation to iron status, is the finding of a relatively high prevalence of IDA (26%) among the female adolescents. This has potentially serious health repercussions such as reduced general health and well-being, reproductive performance, work capacity and impaired cognition which may lead to lower academic performance. As a result, IDA not only has physiological consequences to humans, but also has serious implications for economic and social develop-ment. Therefore, the primary health care system should not only focus on pregnancy (through the provision of nutrient supplements and routine medical examination during the antenatal and postnatal period) and/or immunisation and food supplementary feeding programs targeted at infants and young children. Adolescent health care should also become a high priority in Malaysia, together with infants, young children and pregnant women, as anaemia remains a major nutritional problem. There is a need to expand the iron supplementation strategy to other vulnerable groups such as adolescents. A recent study in Malaysia has shown that weekly combination of iron and folate supplementation can be a safe, effective and inexpensive approach to improve long-term iron status of adolescent girls.[5] Targeting ado-lescents, especially female adolescents for reduction of iron deficiency anaemia before childbearing, serves to complement ongoing efforts to address the problems during pregnancy and infancy. This importance is under-scored by adolescence as a period of major physiological changes, including development towards motherhood.

In conclusion, prevalence of iron deficiency anaemia (IDA) in the present study population, especially in the female adolescents, appears to be a significant public health problem with regards to iron deficiency. It appears that the main reason for the poor iron status is the inadequate intake and bioavailability of dietary iron as well as poor intake of other nutrients. It is hoped that the findings from this study will be useful for the development of nutrition education and other intervention programs, including micronutrient supple-mentation and dietary modification towards the eradica-tion of iron deficiency in adolescents for low-income groups. It has been pointed out that there is a serious lack of data on the nutritional status of adolescents. It is there-fore of importance to systematically conduct and docu-ment studies on the nutritional status of adolescents in all parts of Malaysia, including studies into the prevalence, severity and aetiology of iron deficiency anaemia. Priority should, therefore, be given to female adolescents with regards to their iron intake.

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References

1. Looker AC, Dallman PR, Carroll MD, Gunter EW, Johnson CL. Prevalence of iron deficiency in the United States. J Am Med Assoc 1997; 277:973-976.
2. Nelson M, White J, Rhodes C. Haemoglobin, ferritin and iron intakes in British children aged 12-14 years: a preliminary investigation. Br J Med 1993; 70: 147-155.
3. Pourghassem B, Kimiagar GSM, Abolfathi AA, Vallaii N, Ghaffarpour M. Prevalence of iron deficiency, anaemia and iron-deficiency anaemia in high-school students in Jolfa, East Azerbaijan. Food Nutr Bull 2000; 21: 301-310.
4. UNICEF/ UNU/ WHO/ MI. Preventing Iron Deficiency in Women and Children: Technical Consensus on Key Issues. Technical Workshop, October 7-9, 1998. Boston and Ottawa: International Nutrition Foundation and MI. 1999.
5. Tee ES, Kandiah M, Narimah A, Chong SM, Satgunasingam N, Kamarudin L, Milani S, Dugdale AE, Viteri FE. School-administered weekly iron/ folate supplements improve haemoglobin and ferritin levels of Malaysian adolescent girls. Am J Clin Nutr 1999; 69: 1249-1256.
6. Tee ES, Khor GL, Ng TKW, Zaitun Y, Chee HL, Safiah MY. Nutritional assessment of rural villages and estates in Peninsular Malaysia. III. Prevalence of anaemia. Mal J Nutr 1998; 4: 1-30.
7. Bruner AB, Joffe E, Duggan AK, Casella JF, Brandt J. Randomised study of cognitive effects of iron supplementation in non-anemic iron-deficient adolescent girls. Lancet 1996; 348: 992-996.
8. Darnton-Hill I, Boer AD, Nishida C. Overview of the nutrition in the western pacific region of the world health organization. Aust J Nutr Diet 1996; 53: 171-174.
9. Pollitt E. Iron deficiency and educational deficiency. Nutr Rev 1997; 55: 133-141.

10. Zhu TI, Haas JD. Iron depletion without anaemia and physical performance in young women. Am J Clin Nutr 1997; 66: 334-341.
11. Rajagopalan S, Vinodkumar M. Effects of salt fortified with and iodine on the haemoglobin levels and productivity of tea pickers. Food Nutr Bull 2000; 21: 323-329.
12. Tee AC, Fatimah H, Menaka N. Anaemia, iron deficiency and thalassemia in infants aged 6-24 months of age. Mal J Child Health 1994; 6: 85-93.
13. Chen PCY, Chan MKC, Teoh ST, Bent B, Yap SB, Fong T, Ong FPT, Lee MCC. A nutrition study of the Interior, West Coast and Kudat divisions of Sabah. Department of Social and Preventive Medicine, Faculty of Medicine, University of Malaya, and office of the Director of Medical Services Sabah, Kota Kinabalu, 1981.
14. Kandiah M, Lee MCC, Ng TKW, Chong YH. Malnutrition in malaria endemic villages of Bengkoka Peninsula, Sabah. J Trop Paediatrc 1984; 30: 23-29.
15. Zulkifli A, Jaafar R, Hashim MH, Shukri O, Hashim A. Anaemia during pregnancy in rural Kelantan. Mal J Nutr 1997; 3: 83-90.
16. Beard JL. Iron requirements in adolescent females. Am J Clin Nutr 2000; 130: 440S-442S.
17. WHO. Technical Report Series no. 854. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. Geneva: World Health Organization, 1995.
18. International Committee for Standardization in Haematology (ICSH). The assignment of values to fresh blood used for calibrating automated cell counters. Clinical and Laboratory Haematology 1988; 10: 203-212.
19. International Committee for Standardization in Haematology (ICSH). Protocol for evaluation of automated blood cell counters. Clinical and Laboratory Haematology 1988; 10: 213.
20. Tee ES, Ismail MN, Nasir MA, Khatijah I. Nutrient composition of Malaysian Foods. Malaysian Food Composition Database Programme. 4th Edition c/o Institute for Medical Research, Kuala Lumpur 1997.
21. Teoh ST. Recommended daily dietary intakes for Peninsular Malaysia. Med J Mal 1975; 30: 38-42.
22. Dreyfuss ML, Stoltzfus RJ, Shrestha JB, Pradhan EK, LeClerq SC, Khatry SK, Shrestha SR, Katz J, Albonico M, West KP, Jr. Hookworms, malaria and vitamin A deficiency contribute to anaemia and iron deficiency among pregnant women in the plains of Nepal. J Nutr 2000; 130: 2527-2536.
23. Cook JD, Finch CA. Assessing iron status of a population. Am J Clin Nutr 1979; 32: 2115-2119.
24. Federation of American Societies for Experimental Biology (FASEB)- Expert Scientific Working Group. Summary of a report on assessment of the iron nutritional status of the United States population. Am J Clin Nutr 1985; 42: 1318-1330.
25. WHO. Guildelines for the control of iron deficiency. Report of the WHO/ UNICEF Consultation on strategies for the control of iron deficiency anaemia. Geneva: World Health Organization, 1996.
26. WHO. Technical Report Series no. 797. Diet, nutrition and the prevention of chronic diseases. Geneva: World Health Organization, 1990.
27. Milman N, Clausen J, Byg KE. Iron status in 268 Danish women aged 18-30 years: influence of menstruation, contraceptive method, and iron supplementation. Ann Hematol 1998; 77: 13-19.
28. Samuelson G, Bratteby LE, Berggren K, Elverby JE, Kempe B. Dietary iron intake and iron status in adolescents. Acta Paediatr 1996; 85: 1033-1038.
29. Milman N, Ulrik CS, Graudal N, Jordal R. Iron status in young Danes. Evaluation by serum ferritin and haemoglobin in a population survey of 634 individuals aged 14-23 yr. Eur J Haematol 1997; 58: 160-166.
30. Poh BK, Zawiah H, Ismail MN, Henry CJK. Changes in body weight, dietary intake and activity pattern of adolescents during Ramadan. Mal J Nutr 1996; 2: 1-10.
31. Frost-Andersen L, Nes M, Sandsrad B, Bjorneboe GEA, Drevon CA. Dietary intake among Norwegian adolescents. Eur J Clin Nutr 1995; 49: 555-564.
32. Samuelson G, Bratteby LE, Enghardt H, Hedgren M. Food habits and energy and nutrient intake in Swedish adolescents approaching the year 2000. Acta Paediatr 1996; 415: 1-20.
33. Kuizon MD, Natera MG, Ancheta LP, Platon TP, Desnacido JA, Macapinlac MP. Assessment of the iron status of Filipino adolescents. Southeast Asian J Trop Med Pub Hlth 1982; 13: 81-85.
34. Tatala S, Svanberg Uif Mduma B. Low dietary iron bioavailability is a major cause of anaemia: a nutrition survey in the Lindi District of Tanzania. Am J Clin Nutr 1998; 68: 171-178.