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High prevalence of malnutrition and vitamin A deficiency among schoolchildren of rural areas in Malaysia using a multi-school assessment approach

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Abstract

Childhood malnutrition is known as a public health concern globally. The present study aims to assess the anthropometry and blood biochemical status of rural primary schoolchildren in Malaysia. A total of 776 children (7–11 years old) from ten rural primary schools from five states were included in this study. Nutritional outcomes were assessed based on sex, age group and school categories among the children (median age: 9 years (P25:8, P75:10)). The overall prevalence of malnutrition was 53·4 %. Vitamin A deficiency (VAD) was recorded at 20·6 and 39·8 % based on retinol and retinol-binding protein (RBP) levels, respectively. Anaemia, iron deficiency (ID), iron-deficiency anaemia (IDA) and elevated inflammation were found at 14·9, 17·9, 9·1 and 11·5 %, respectively. Malnutrition, VAD, anaemia, ID, IDA and elevated inflammation were more prevalent among Orang Asli (OA) schoolchildren compared with Non-Orang Asli schoolchildren. Higher occurrences of VAD and anaemia were also found among children aged <10 years. Retinol, RBP, α-carotene, ferritin and haemoglobin levels were lower among undernourished children. Besides, overweight/obese children exhibited a higher level of high-sensitivity C-reactive protein. Multivariate analysis demonstrated that OA school children (adjusted OR (AOR): 6·1; 95 % CI 4·1, 9·0) and IDA (AOR: 3·6; 95 % CI 1·9, 6·6) were associated with stunting among this population. The present study revealed that malnutrition, micronutrient deficiencies and anaemia are prevalent among rural primary schoolchildren in Malaysia, especially those from OA schools and younger age children (<10 years). Hence, more appropriate and targeted measures are needed to improve the nutritional status of these children.

Keywords: **Malnutrition: Vitamin A deficiency: Anaemia: Iron Deficiency: Inflammation**

Global malnutrition among children is primarily targeted at children aged less than five. WHO reported that an estimated 149 million and 45 million children aged under 5 years were stunted and wasted, respectively, whereas 38 million were overweight or obese globally[1]. In contrast, school-age children are scarcely monitored globally despite the significant impact of malnutrition on their health, cognitive function, academic performance and future economic productivity[2,3].

In Malaysia, it is known that malnutrition among children remains a health concern despite steady economic growth in the past decades. The Malaysian National Health and Morbidity Survey (NHMS) 2019 reported that the prevalences of stunting (height-for-age z-score (HAZ) < −2 SD), thinness (BMI-for-age z-score (BAZ) < −2 SD) and underweight (weight-for-age z-score (WAZ) < −2 SD), among children aged 5–17 years, were 12·7, 10·0 and 15·4 %, respectively[4]. Besides, 15·0 and 14·8 % of the same group of children were found to be overweight (2 SD < BAZ ≤ 3 SD) and obese (BAZ > 3 SD), respectively[4], thus highlighting the phenomenon of double burden.

Throughout childhood, micronutrients play significant roles in immune function, energy production, learning and cognitive functions[5]. It is estimated that micronutrient deficiencies affect at least 340 million children aged under five globally[6]. Vitamin A deficiency (VAD) is a significant public health problem affecting about one-third of children aged less than five in 1995–2015, with Southeast Asia recording the highest prevalence at

Abbreviations: HAZ, Height-for-age z-score; BAZ, BMI-for-age z-score; WAZ, weight-for-age z-score; COR, crude OR; hs-CRP, high-sensitivity C-reactive protein; ID, iron deficiency; IDA, iron-deficiency anaemia; NOA, Non-Orang Asli; OA, Orang Asli; RBP, retinol-binding protein; SES, socio-economic status; VAD, vitamin A deficiency.

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49·9 %[7]. VAD affects normal haematopoiesis, Fe metabolism and immune function[8] due to inadequate vitamin A intake or reduced availability of pro-vitamin A, namely carotenoids[9].

South-East Asian Nutrition Survey (SEANUTS) Malaysia reported a prevalence of 4·4 % VAD among children aged 6 months to 12 years old, with higher prevalence recorded in rural areas (6·4 %) compared with urban areas (3·8 %)[10]. In the same survey, it was found that the overall prevalences of iron deficiency (ID) and anaemia were 4·4 and 6·6 %, respectively. In addition, based on several studies conducted among Orang Asli (OA) (indigenous) schoolchildren, the prevalence of anaemia ranged from 26·2 % to 68·4 %, while VAD prevalence was at 27·4 %, and 36·7–54·9 % of them were found to be Fe deficient[11–14]. OA, which transliterates as original people in the Malay language, is the indigenous minority peoples of Peninsular Malaysia, which account for 0·7 % of the population of Peninsular Malaysia[15].

Despite nationwide anthropometric data being highly accessible as indicators of nutritional status in Malaysia, there are limited coherent and updated data on other nutrition and health indicators among children, mainly primary school-age children from rural areas. Thus, this study aims to collate data on the anthropometry and blood biochemical status of primary schoolchildren aged between 7 and 11 years old in the rural areas of Malaysia. The selected micronutrients (vitamin A, α-carotene, β-carotene and vitamin E), haemoglobin (Hb) status, ferritin status (indicator for ID), inflammation status and their associations with the nutritional status of the children were discussed in the present study. Potential socio-economics- and blood biochemical-related factors associated with stunting, the most prevalent malnutrition problem among this population, were examined.

Method

Study areas and subjects

This cross-sectional study was carried out between April 2017 and October 2017. Ten national primary schools from five different states located in rural areas of Malaysia were randomly selected based on suggestions and lists from the Ministry of Education (MOE) and Department of Orang Asli Development (JAKOA), taking into consideration the following criteria: (i) approval by the Ministry of Health (MOH) and MOE; (ii) schools with a population of at least fifty children; (iii) socio-economic status (SES) is generally poor; (iv) accessible by road transportation (for rapid transportation of samples to the laboratory for preservation and storage); (v) Malaysian children aged 7–11 years old and (vi) healthy at the point of the study period.

Among the selected schools, five schools are OA schools consisting of OA majority students (mainly of Semai and Temiar subgroups) and located in the vicinity of indigenous villages. At the same time, another five are Non-Orang Asli (NOA) schools consisting of NOA students (mainly of Malay, Kadazandusun and Iban ethnicities). The locations of the selected schools are shown in Fig. 1. Absent or ill children during the period of study were excluded.

The sample size was calculated based on the prevalence of stunting in rural areas at 12·7 %, as reported by NHMS 2019[4] according to the following formula[16]:

$$n \geq (z/m)^2 \times p(1-p) \quad (3)$$

where n is the minimum sample size, z is the standard score (1·96), m is the rate of sampling error (5 %) and p is the estimated prevalence of the variable in the population. At a significance level of 5 % and a confidence level of 95 %, a minimum sample size of 218 participants was required for this study.

Ethical approval, consent and socio-demographic data collection

The study was conducted according to the guidelines laid down in the Declaration of Helsinki. All procedures involving human subjects were approved by the Medical Research and Ethics Committee, MOH, Malaysia (NMRR-16–1905–32 547). Before the commencement of the study, the participants and parents/guardians were given an oral briefing on the objectives and methodology of the study. They were also informed that their child's participation was voluntary, and therefore they could withdraw from the study at any time. For all the literate guardians, written informed consents were obtained before the study commenced. As for illiterate guardians, verbal consents were obtained, followed by their thumbprint on the informed consent form. All the verbal consents were witnessed and formally recorded. Besides, an assent form was signed by the children themselves. Socio-demographic data, including age, sex and monthly household income of the children, were collected from student database obtained from the respective school's administration and parents. Monthly household income was categorised into two groups (<RM500 and ≥ RM500). A monthly household income of <RM500 was regarded as being below the Malaysia poverty income threshold[17]. The trial was registered on ClinicalTrials.gov with identification number NCT03256123 and can be accessed at https://clinicaltrials.gov/.

Anthropometric assessment

Height and weight measurements were performed using SECA Clara 803 and SECA 213 mobile stadiometer. The height measuring device was placed near the wall according to the device manual. During height measurement, students were requested to remove any footwear or hair accessories that may obstruct measurements. Height was recorded to the nearest 0·1cm. Before weight measurement was conducted, students were asked to empty their pockets. Calibrated SECA weighing scale was placed on a level surface. Each student was instructed to stand barefoot with minimal clothing and empty pockets at the centre of the scale. The weight was recorded to the nearest 0·1 kg. To reduce intra-observer error, height and weight were measured twice and the mean value was used for analysis. BMI was computed by dividing the measured weight (kg) by the square of height (m).

Anthropometric indices were computed using *anthro* R-package provided by WHO[18]. There were three anthropometric indices: (a) HAZ to assess stunting and (b) BAZ to assess thinness, overweight and obesity and (c) WAZ to assess underweight. All three anthropometric indices were expressed as differences from the median in standard deviation units or z-scores. Students were classified as stunted, thin and underweight if HAZ, BAZ and WAZ were less than 2 SD below the

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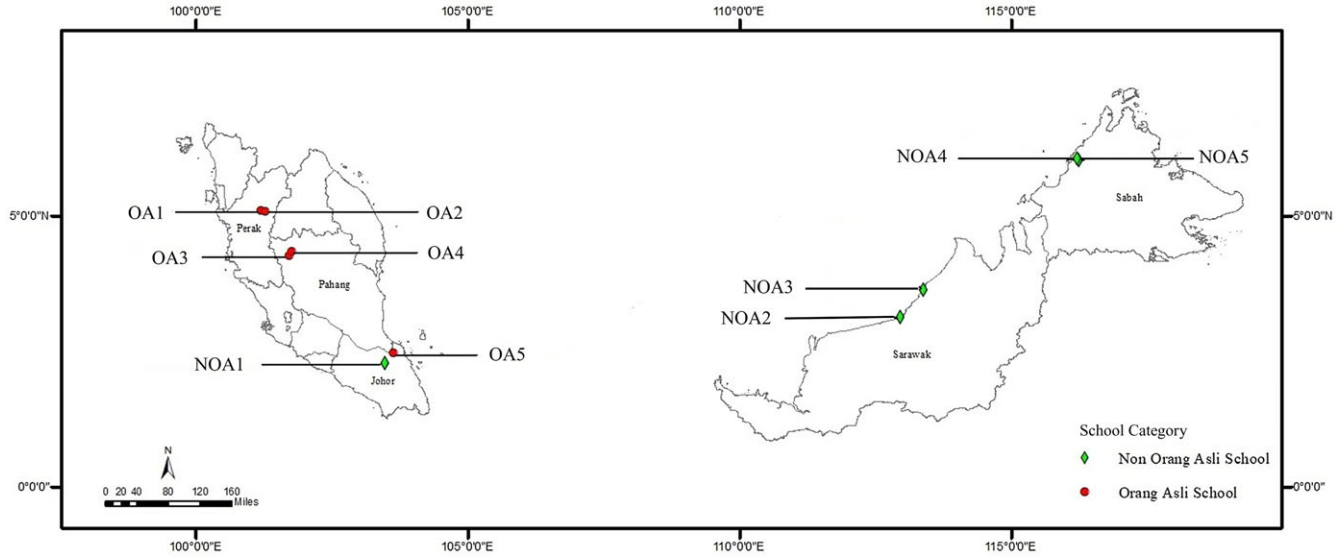

Fig. 1. Locations of the selected schools in Peninsular, Sabah and Sarawak of Malaysia. In total, ten national primary schools from five different states located in rural areas of Malaysia were selected. Among the selected schools, five schools are Orang Asli (OA) schools consisting majority of OA students (mainly of Semai and Temiar subgroups) and located in the vicinity of indigenous villages. Another five are Non-Orang Asli (NOA) schools consisting of NOA students (mainly of Malay, Kadazandusun and Iban ethnicities).

WHO reference median[19]. On the other hand, BAZ value 1 and 2 SD above WHO reference median were used to determine overweight and obesity status, respectively[19].

Blood biochemical assessments

Blood collection was conducted within a week of the anthropometric measurements. After an overnight fast (10 h), approximately 6 ml of venous blood was collected by trained nurses and medical assistants from MOH. Vacutainer tubes were covered with aluminium foil to prevent direct exposure to sunlight and kept in an icebox surrounded by ice and ice packs. The blood samples were then transported back to the Nutrition Unit Laboratory in Malaysian Palm Oil Board (MPOB), Bangi, Selangor, on the same day of collection for processing. An automated haematology analyser performed a complete blood count on the same day (Sysmex XN-10). The rest of the blood tubes were centrifuged at 3000 rpm for 15 min at 4°C to obtain serum and plasma and were stored at –80°C until further analysis.

Plasma retinol, α-carotene, β-carotene and α-tocopherol (vitamin E) levels were measured using reverse-phase HPLC (Agilent 1260 Infinity) as described by Kand'ár *et al.*[20]. Briefly, plasma samples were extracted twice with hexane, while retinyl acetate and α-tocopheryl acetate were used as internal standards. The mean recovery of retinyl acetate and α-tocopheryl acetate was 94·45 (SD 3·34) % and 97·73 (SD 3·44) %, respectively. Retinol-binding protein (RBP) was measured by quantitative sandwich enzyme immunoassay (R&D Systems). VAD was defined by both retinol and RBP concentrations at <0·70 μmol/l, while marginal VAD was defined when the concentrations were at 0·70 to <1·05 μmol/l[21,22].

Anaemia was diagnosed when a complete blood count test shows Hb concentration <115 g/l, and further classified by the degree of severity into severe (<80 g/l), moderate (80–109 g/l) and mild (110–114 g/l)[23]. The concentration of serum ferritin was measured by two-site sandwich immunoassay via a direct chemiluminescence method using ADVIA Centaur (Siemens). Serum ferritin value of <15 μg/l was considered as ID, while iron-deficiency anaemia (IDA) was defined as ID concurrent with anaemia[11,24]. High-sensitivity C-reactive protein (hs-CRP) was measured using an immunoturbidimetric method. hs-CRP concentration > 5·0 mg/l was considered as having a high inflammatory response[25]. All these procedures on Hb, serum ferritin and hs-CRP were conducted at an accredited laboratory, Pathology & Clinical Laboratory (M) Sdn. Bhd., Malaysia.

Statistical analysis

Data collected were entered and analysed using the Statistical Package for the Social Sciences (IBM SPSS Statistics) programme for Windows version 22. Before analysis was carried out, data entered were cross-checked on a timely basis to ensure all the data were entered accurately. For descriptive data, count (percentage) was used. Kolmogorov–Smirnov Z test was used to examine the normality of quantitative data. As most of the data did not meet the criterion of a normal distribution, the distribution of continuous data was presented as the median and interquartile range (25th, 75th percentiles; P25, P75). Mann–Whitney U test or Kruskal–Wallis H test (followed by Dunn's multiple comparison test as appropriate) was used to test for differences between continuous variables with two or more than two groups, respectively. Categorical variables are reported as percentages and compared by the χ^2 test. Univariate and multivariate logistic regressions were performed to examine the potential factors associated with stunting. All variables that were significantly associated with stunting in univariate model were included in a logistic multivariate analysis using forward elimination model, and presented as the crude OR (COR) and adjusted

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OR with 95 % CI. Model fitness was assessed by the Hosmer–Lemeshow goodness of fit test. A value of $P < 0{\cdot}05$ was considered statistically significant.

Results

Socio-demographic characteristics

Table 1 demonstrates the socio-demographic characteristics of the overall population. A total of 776 children (379 boys and 397 girls) aged 7–11 years were included in the final analysis. Overall, there were 458 (59 %) children aged <10 years and 318 (41 %) children aged ≥ 10 years with a median age of 9 years (P25:8, P75:10). No significant difference was observed for age between sexes. The highest number of children was recruited from the states of Pahang (36·6 %), followed by Perak (21·8 %), Sarawak (18·4 %), Johor (12·4 %) and Sabah (10·8 %). More than half of the population (63·8 %) were studying in OA schools, and the majority (93 %) were from <RM 500 monthly household income families.

Table 1. Socio-demographic characteristics of the overall population (Numbers and percentages, median and percentiles, *n*=776)

Characteristics	*n*	%
Age (years)		
Median	9	
25th percentile, 75th percentile	8, 10	
Sex		
Boys	379	48·7
Girls	397	51·0
Age group		
<10 years old	458	59·0
≥ 10 years old	318	41·0
State		
Pahang	284	36·6
Perak	169	21·8
Johor	96	12·4
Sarawak	143	18·4
Sabah	84	10·8
School category		
Orang Asli School	497	63·8
Non-Orang Asli School	279	35·8
Monthly household income		
<RM 500	715	93·0
≥ RM 500	54	7·0

Anthropometric characteristics

Overall, it was found that 53·4 % of children have malnutrition problems, with 34·9, 4·8 and 30·5 % of the children were stunted, thin and underweight (only included children aged <10 years, *n*=551), respectively, while 15·5 % were found to be overweight/obese (Table 2). Among stunted children, 29·9 % were severely stunted children, while for those who were underweight, 26·2 % were severely underweight. In addition, 29·7 % of children were found to be severely thin among those who had thinness problems. Similar anthropometric characteristics were observed between sex and age group (Table 2).

The previous analyses based on age and sex among the population showed no significant difference, hence we further analysed the population based on school category. Children from OA schools were found to have significantly lower values of anthropometric measurements, including height, weight, BMI, HAZ, BAZ and WAZ compared with children from NOA schools ($P < 0{\cdot}001$). In addition to that, the prevalences of stunting and underweight among children in OA schools (47·3 and 40·0 %) were more than three times higher than in NOA schools (11·8 and 12·9 %) ($P < 0{\cdot}001$). On the other hand, NOA schoolchildren had significantly higher prevalences of overweight and obesity (11·8 and 12·2 %) than their counterparts (6·8 and 3·8 %).

Biochemical characteristics

Generally, the children aged ≥ 10 years exhibited significantly higher values for all the blood parameters than those aged <10 years old except α-tocopherol, serum ferritin and hs-CRP, where they exhibited higher but not significantly different ($P \geq 0{\cdot}05$) (Table 3). By sex, a higher value of α-tocopherol was observed among girls (8·01 μmol/l (P25:6·89, P75:9·25)) compared with boys (7·67 μmol/l (P25:6·62, P75:8·91)) ($P = 0{\cdot}03$). On the other hand, ferritin level in girls (34·0 μg/l (P25:21·0, P75:54·0) was significantly lower compared with boys (53·0 μg/l (P25:28·0, P75:76·0)) among children aged ≥ 10 years ($P < 0{\cdot}001$) (data not shown).

Overall, the prevalence of VAD based on retinol and RBP levels was 20·6 and 39·8 %, respectively (Table 2). More than half of the children suffered from a marginal deficiency of retinol (56·8 %), and nearly half of them were found to have a marginal deficiency of RBP levels (47·8 %). The overall prevalence of anaemia was 14·9 %. Nearly half of the anaemic children exhibited mild anaemia (48·3 %) and moderate anaemia (49·1 %), while only 2·6 % had severe anaemia. A higher prevalence of VAD, based on both retinol and RBP level <0·7 μmol/L, was observed among children aged <10 years (23·4 and 43·7 %) when compared with their older counterparts (16·7 and 34·3 %) (Table 3). Also, the prevalence of anaemia among children aged <10 years (19·2 %) was about two times higher than their older counterparts (8·8 %) ($P < 0{\cdot}001$) (Table 3).

Table 3 shows the biochemical characteristics of children from both OA and NOA schools. OA schoolchildren were observed to have significantly lower concentrations of retinol (0·83 μmol/l (P25:0·69, P75:0·97)), RBP (0·70 μmol/l (P25:0·58, P75:0·82)), α-carotene (0·06 μmol/l (P25:0·04, P75:0·08)), Hb (124·0 g/l (P25:117·0, P75:129·0)) and ferritin (35·0 μg/l (P25:19·5, P75:62·5)). In contrast, the concentrations of α-tocopherol (8·03 μmol/l (P25:6·94, P75:9·25)), β-carotene (0·30 μmol/l (P25:0·20, P75:0·43)) and hs-CRP (0·2 mg/l (P25:0·2, P75:1·2)) were found to be significantly higher among the OA schoolchildren. Moreover, VAD based on both retinol (27·8 %) and RBP (51·1 %) parameters was more prevalent among OA schoolchildren. Higher occurrences of anaemia (20·1 %), ID (17·9 %), IDA (9·1 %) and high inflammation (hs-CRP levels > 5·0 mg/l) (11·5 %) were noted in the same group of children.

Biochemical measurements in relation to nutritional status

Table 4 illustrates the median levels of biochemical measurements in relation to the nutritional status determined by anthropometric indicators. In general, significantly lower levels of retinol, RBP, α-carotene, Hb and ferritin were perceived

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Table 2. Anthropometric characteristics of the children stratified by school category, age group and sex (Median values and percentiles, numbers and percentages, n=776)[‖]

			School category						
	Overall (n=776)		Orang Asli school (n=497)		Non-Orang Asli school (n=279)				
Characteristics	Median	25th percentile, 75th percentile	Median	25th percentile, 75th percentile	Median	25th percentile, 75th percentile	Median difference	95 % CI[¶]	P
Height (cm)	123·3	116·5, 130·4	120·8	114·0, 126·5	129·0	121·0, 135·2	−7·9	−9·3, −6·4	<0·001***
Weight (kg)	23·8	20·0, 29·2	22·1	19·0, 26·8	26·7	22·5, 33·1	−4·7	−5·7. −3·7	<0·001***
BMI (kg/m^2)	15·5	14·5, 17·2	15·2	14·2, 16·7	16·1	15·1, 18·7	−1·0	−1·4, −0·7	<0·001***
HAZ	−1·6	−2·3, −0·9	−1·9	−2·7, −1·3	−1·0	−1·6, −0·2	−1·1	−1·2, −0·9	<0·001***
BAZ	−0·4	−1·0, 0·5	−0·6	−1·1, 0·2	0·0	−0·8, 0·9	−0·6	−0·8, −0·4	<0·001***
WAZ[‡]	−1·4	−2·3, −0·4	−1·7	−2·4, −0·8	−0·6	−1·4, 0·4	−1·1	−1·4, −0·9	<0·001***
	n	%	n	%	n	%			
Malnutrition status§									
Malnutrition	414	53·4	302	60·8	112	40·1			<0·001†††
Normal	362	46·6	195	39·2	167	59·9			
HAZ status									
Stunting (HAZ < −2)	271	34·9	235	47·3	36	12·9			<0·001†††
Normal (HAZ ≥ −2)	505	65·1	262	52·7	243	87·1			
Categories of HAZ status									
Severe stunting (HAZ < −3)	81	10·4	77	15·5	4	1·4			<0·001†††
Moderate stunting (−3 ≤ HAZ < −2)	190	24·5	158	31·8	32	11·5			
BAZ status									
Thinness (BAZ < −2)	37	4·8	28	5·6	9	3·2			<0·001†††
Overweight/Obese (BAZ > 1)	120	15·5	53	10·7	67	24·0			
Normal (−2 ≤ BAZ ≤ 1)	619	79·8	416	83·7	203	72·8			
Categories of BAZ status									
Severe thinness (BAZ < −3)	4	0·5	3	0·6	1	0·4			<0·001†††
Moderate thinness (−3 ≤ BAZ < −2)	33	4·3	25	5·0	8	2·9			
Overweight (1 < BAZ ≤ 2)	67	8·6	34	6·8	33	11·8			
Obese (BAZ > 2)	53	6·8	19	3·8	34	12·2			
WAZ status‡									
Underweight (WAZ < −2)	168	30·5	146	40·0	22	11·8			<0·001†††
Normal (WAZ ≥ −2)	383	69·5	219	60·0	164	88·2			
Grade of WAZ status‡									
Severe underweight (WAZ < −3)	44	8·0	40	11·0	4	2·2			<0·001†††
Moderate underweight (−3 ≤ WAZ < −2)	124	22·5	106	29·0	18	9·7			

	Age group							Sex					
	<10 (n=458)		≥ 10 (n=318)					Boys (n=379)		Girls (n=397)				
Characteristics	Median	25th percentile, 75th percentile	Median	25th percentile, 75th percentile	Median difference	95 % CI[¶]	P	Median	25th percentile, 75th percentile	Median	25th percentile, 75th percentile	Median difference	95 % CI[¶]	P
Height (cm)	118·8	113·0, 124·1	130·5	124·4, 136·1	−11·8	−13·0, −10·6	<0·001***	123·0	116·2, 130·4	123·5	117·0, 130·4	−0·7	−2·2, 0·7	0·32
Weight (kg)	21·2	18·6, 25·3	27·7	23·7, 33·1	−6·2	−7·0, −5·3	<0·001***	23·2	19·8, 28·4	24·3	20·0, 29·6	−0·4	−1·3, 0·5	0·36
BMI (kg/m^2)	15·1	14·2, 16·6	16·2	15·0, 18·1	−1·0	−1·3, −0·7	<0·001***	15·4	14·5, 17·1	15·6	14·3, 17·2	0·0	−0·3, 0·3	0·87
HAZ	−1·6	−2·3, −0·8	−1·7	−2·4, −0·9	0·1	−0·1, 0·3	0·33	−1·6	−2·4, −0·9	−1·6	−2·3, −0·8	−0·1	−0·2, 0·1	0·38
BAZ	−0·4	−1·0, 0·5	−0·3	−1·0, 0·5	−0·1	−0·2, 0·1	0·55	−0·5	−1·0, 0·5	−0·3	−1·0, 0·5	0·0	−0·2, 0·2	0·90
WAZ‡	−1·3	−2·2, −0·2	−1·4	−2·4, −0·6	0·3	−0·1, 0·6	0·11	−1·5	−2·3, −0·4	−1·3	−2·1, −0·2	−0·2	−0·5, 0·0	0·07

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Table 2. (*Continued*)

Characteristics	Age group							Sex						
	<10 (*n*=458)		≥ 10 (*n*=318)					Boys (*n*=379)		Girls (*n*=397)				
	Median	25th percentile, 75th percentile	Median	25th percentile, 75th percentile	Median difference	95 % CI¶	*P*	Median	25th percentile, 75th percentile	Median	25th percentile, 75th percentile	Median difference	95 % CI¶	*P*
	n	%	*n*	%				*n*	%	*n*	%			
Malnutrition status§														
Malnutrition	238	52·0	176	55·3			0·35	215	56·7	199	50·1			0·07
Normal	220	48·0	142	44·7				164	43·3	198	49·9			
HAZ status														
Stunting (HAZ < –2)	152	33·2	119	37·4			0·22	136	35·9	135	34			0·58
Normal (HAZ ≥ –2)	306	66·8	199	62·6				243	64·1	262	66·0			
Categories of HAZ status														
Severe stunting (HAZ < –3)	43	9·4	38	11·9			0·39	43	11·3	38	9·6			0·71
Moderate stunting (–3 ≤ HAZ < –2)	109	23·8	81	25·5				93	24·5	97	24·4			
BAZ status														
Thinness (BAZ < –2)	19	4·1	18	5·7			0·43	22	5·8	15	3·8			0·16
Overweight/Obese (BAZ > 1)	67	14·6	53	16·7				65	17·2	55	13·9			
Normal (–2 ≤ BAZ ≤ 1)	372	81·2	247	77·7				292	77·0	327	82·4			
Categories of BAZ status														
Severe thinness (BAZ < –3)	2	0·4	2	0·6			0·64	2	0·5	2	0·5			0·33
Moderate thinness (–3 ≤ BAZ < –2)	17	3·7	16	5·0				20	5·3	13	3·3			
Overweight (1 < BAZ ≤ 2)	35	7·6	32	10·1				34	9·0	33	8·3			
Obese (BAZ > 2)	32	7·0	21	6·6				31	8·2	22	5·5			
WAZ status‡														
Underweight (WAZ < –2)	135	29·5	33	35·5			0·25	91	33·6	77	27·5			0·12
Normal (WAZ ≥ –2)	323	70·5	60	64·5				180	66·4	203	72·5			
Grade of WAZ status‡														
Severe underweight (WAZ < –3)	35	7·6	9	9·7			0·51	24	8·9	20	7·1			0·30
Moderate underweight (–3 ≤ WAZ < –2)	100	21·8	24	25·8				67	24·7	57	20·4			

WAZ, weight-for-age z-score; HAZ, height-for-age z-score; BAZ, BMI-for-age z-score.
Significant difference based on Mann–Whitney U test: **P* < 0·05; ***P* < 0·01; ****P* < 0·001.
Significant difference based on χ^2 test: †*P* < 0·05; ††*P* < 0·01; †††*P* < 0·001.
‡ Only included children aged ≤ 10 years old (*n*=551).
§ Children with any form of malnutrition (stunting, thinness, overweight and underweight).
‖ Data presented as median (25th percentile, 75th percentile) or *n* (%).
¶ Hodges–Lehmann estimation and its associated 95 % CI.

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Table 3. Biochemical characteristics of the children stratified by school category, age group and sex (Median values and percentiles, numbers and percentages, *n*=776)‡

Characteristics	Overall (*n*=776)		School category						
			Orang Asli School (*n*=497)		Non-Orang Asli School (*n*=279)				*P*
	Median	25th percentile, 75th percentile	Median	25th percentile, 75th percentile	Median	25th percentile, 75th percentile	Median difference	95 % CI§	
Retinol (μmol/l)	0·88	0·74, 1·03	0·83	0·69, 0·97	0·99	0·86, 1·17	−0·18	−0·21, −0·14	<0·001***
RBP (μmol/l)	0·75	0·63, 0·91	0·70	0·58, 0·82	0·88	0·72, 1·03	−0·17	−0·20, −0·14	<0·001***
α-tocopherol (μg/ml)	7·81	6·82, 9·06	8·03	6·94, 9·25	7·51	6·55, 8·67	0·43	0·19, 0·68	<0·001***
α-carotene (μg/ml)	0·06	0·04, 0·09	0·06	0·04, 0·08	0·07	0·04, 0·11	−0·01	−0·02, −0·01	<0·001***
β-carotene (μg/ml)	0·28	0·20, 0·42	0·30	0·20, 0·43	0·26	0·17, 0·39	0·03	0·01, 0·06	0·006**
Hb (g/l)	126·0	118·0, 133·8	124·0	117·0, 129·0	132·0	126·0, 138·0	−9·0	−11·0, −8·0	<0·001***
Ferritin (μg/l)	40·0	24·0, 62·0	35·0	19·5, 62·5	44·0	30·0, 62·0	−8·0	−12·0, −4·0	<0·001***
hs–CRP (mg/l)	0·2	0·2, 1·0	0·2	0·2, 1·2	0·2	0·2, 0·7	0·0	0·0, 0·0	0·03*
Vitamin A deficiency	*n*	%	*n*	%	*n*	%			
Retinol level									
Deficiency (<0·70 μmol/l)	160	20·6	138	27·8	22	7·9			<0·001†††
Marginal deficiency (0·70–<1·05 μmol/l)	441	56·8	296	59·6	145	52·0			
Sufficient (≥ 1·05 μmol/l)	175	22·6	63	12·7	112	40·1			
RBP level									
Deficiency (<0·70 μmol/l)	309	39·8	254	51·1	55	19·7			<0·001†††
Marginal deficiency (0·70–<1·05 μmol/l)	371	47·8	212	42·7	159	57·0			
Sufficient (≥ 1·05 μmol/l)	96	12·4	31	6·2	65	23·3			
Anaemia									
Yes (Hb <115 g/l)	116	14·9	100	20·1	16	5·7			<0·001†††
No (Hb ≥ 115 g/l)	660	85·1	397	79·9	263	94·3			
Grade of anaemia									
Severe (Hb <80 g/l)	3	0·4	3	0·6	0	0			<0·001†††
Moderate (Hb 80–109 g/l)	57	7·3	48	9·7	9	3·2			
Mild (Hb 110–114 g/l)	56	7·2	49	9·9	7	2·5			
Iron deficiency									
Yes (ferritin <15 μg/l)	99	12·8	89	17·9	10	3·6			<0·001†††
No (ferritin ≥ 15 μg/l)	677	87·2	408	82·1	269	96·4			
Iron-deficiency anaemia									
Yes (Hb <115 g/l and ferritin <15 μg/l)	47	6·1	45	9·1	2	0·7			<0·001†††
No (Hb ≥ 115 g/l or ferritin ≥ 15 μg/l)	729	93·9	452	90·9	277	99·3			
High inflammation									
Yes (hs-CRP > 5·0 mg/l)	76	9·8	57	11·5	19	6·8			0·04†
No (hs-CRP ≤ 5·0 mg/l)	700	90·2	440	88·5	260	93·2			

Characteristics	Age group							Sex						
	<10 (*n*=458)		≥ 10 (*n*=318)					Boys (*n*=379)		Girls (*n*=397)				*P*
	Median	25th percentile, 75th percentile	Median	25th percentile, 75th percentile	Median difference	95 % CI§	*P*	Median	25th percentile, 75th percentile	Median	25th percentile, 75th percentile	Median difference	95 % CI§	
Retinol (μmol/l)	0·86	0·72, 1·01	0·94	0·77, 1·06	−0·07	−0·10, −0·03	<0·001***	0·90	0·74, 1·06	0·87	0·75, 1·02	0·02	−0·02, 0·05	0·30
RBP (μmol/l)	0·73	0·61, 0·88	0·78	0·66, 0·94	−0·05	−0·08, −0·02	0·001**	0·76	0·63, 0·92	0·75	0·64, 0·90	0·00	−0·03, 0·03	0·87
α-tocopherol (μg/ml)	7·78	6·59, 9·01	7·85	6·97, 9·26	−0·20	−0·44, 0·04	0·10	7·67	6·62, 8·91	8·01	6·89, 9·25	−0·26	−0·50, −0·02	0·03*
α-carotene (μg/ml)	0·05	0·03, 0·08	0·07	0·04, 0·10	−0·02	−0·02, −0·01	<0·001***	0·06	0·04, 0·09	0·06	0·04, 0·09	0·00	0·00, 0·00	0·50
β-carotene (μg/ml)	0·26	0·18, 0·39	0·33	0·23, 0·47	−0·07	−0·09, −0·04	<0·001***	0·28	0·19, 0·41	0·29	0·20, 0·44	−0·01	−0·03, 0·01	0·36

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Table 3. (*Continued*)

Characteristics	Age group							Sex						
	<10 (*n*=458)		≥ 10 (*n*=318)					Boys (*n*=379)		Girls (*n*=397)				*P*
	Median	25th percentile, 75th percentile	Median	25th percentile, 75th percentile	Median difference	95 % CI§	*P*	Median	25th percentile, 75th percentile	Median	25th percentile, 75th percentile	Median difference	95 % CI§	
Hb (g/l)	125·0	117·0, 13	128·0	121·0, 137·0	–5·0	–6·0, –3·0	<0·001***	127·0	118·0, 134·0	126·0	119·0, 133·5	0·0	–1·0, 2·0	0·89
Ferritin (μg/l)	39·0	23·0, 62·0	43·0	24·0, 63·0	–2·0	–6·0, 1·0	0·20	44·0	24·0, 67·0	36·0	22·0, 58·0	4·0	1·0, 8·0	0·03*
hs–CRP (mg/l)	0·2	0·2, 1·0	0·2	0·2, 0·9	0·0	0·0, 0·0	0·37	0·2	0·2, 1·1	0·2	0·2, 0·9	0·0	0·0, 0·0	0·45
Vitamin A deficiency	*n*	%	*n*	%				*n*	%	*n*	%			
Retinol level														
Deficiency (<0·70 μmol/l)	107	23·4	53	16·7			0·04†	80	21·1	80	20·2			0·09
Marginal deficiency (0·70–<1·05 μmol/l)	258	56·3	183	57·5				202	53·3	239	60·2			
Sufficient (≥ 1·05 μmol/l)	93	20·3	82	25·8				97	25·6	78	19·6			
RBP level														
Deficiency (<0·70 μmol/l)	200	43·7	109	34·3			0·008††	154	40·6	155	39·0			0·50
Marginal deficiency (0·70–<1·05 μmol/l)	212	46·3	159	50·0				174	45·9	197	49·6			
Sufficient (≥ 1·05 μmol/l)	46	10·0	50	15·7				51	13·5	45	11·3			
Anaemia														
Yes (Hb <115 g/l)	88	19·2	28	8·8			<0·001†††	61	16·1	55	13·9			0·38
No (Hb ≥ 115 g/l)	370	80·8	290	91·2				318	83·9	342	86·1			
Grade of anaemia														
Severe (Hb <80 g/l)	3	0·7	0	0			0·001††	1	0·3	2	0·5			0·58
Moderate (Hb 80–109 g/l)	45	9·8	12	3·8				28	7·4	29	7·3			
Mild (Hb 110–114 g/l)	40	8·7	16	5				32	8·4	24	6·0			
Iron deficiency														
Yes (ferritin <15 μg/l)	63	13·8	36	11·3			0·32	45	11·9	54	13·6			0·47
No (ferritin ≥ 15 μg/l)	395	86·2	282	88·7				334	88·1	343	86·4			
Iron-deficiency anaemia														
Yes (Hb <115 g/l and ferritin <15 μg/l)	34	7·4	13	4·1			0·06	23	6·1	24	6·0			0·99
No (Hb ≥ 115 g/l or ferritin ≥ 15 μg/l)	424	92·6	305	95·9				356	93·9	373	94·0			
High inflammation														
Yes (hs-CRP > 5·0 mg/l)	50	10·9	26	8·2			0·21	31	8·2	45	11·3			0·14
No (hs-CRP ≤ 5·0 mg/l)	408	89·1	292	91·8				348	91·8	352	88·7			

RBP, retinol-binding protein; hs-CRP, high-sensitivity C-reactive protein.
Significant difference based on Mann–Whitney U test: *$P < 0·05$; **$P < 0·01$; ***$P < 0·001$.
Significant difference based on χ^2 test: †$P < 0·05$; ††$P < 0·01$; †††$P < 0·001$.
‡ Data presented as median (25th percentile, 75th percentile) or *n* (%).
§ Hodges–Lehmann estimation and its associated 95 % CI.

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Table 4. Biochemical measurements in relation to the nutritional status of the children
(Median values and percentiles, numbers and percentages, *n*=776)

	Retinol (μmol/l)		RBP (μmol/l)		α-tocopherol (μg/ml)		α-carotene (μg/ml)		β-carotene (μg/ml)		Hb (g/l)		Ferritin (μg/l)		hs-CRP (mg/l)	
	Median	P25, P75	Median	P25, P75	Median	P25, P75	Median	P25, P75	Median	P25, P75	Median	P25, P75	Median	P25, P75	Median	P25, P75
HAZ status																
Stunted (*n*=271)	0·85	0·69, 1·00	0·71	0·60, 0·86	7·91	6·95, 9·24	0·06	0·03, 0·08	0·28	0·20, 0·42	124·0	116·0, 129·0	32·0	18·0, 55·0	0·2	0·2, 0·8
Normal (*n*=505)	0·91	0·78, 1·07	0·77	0·66, 0·93	7·77	6·73, 8·99	0·07	0·04, 0·10	0·29	0·20, 0·42	128·0	120·0, 135·0	45·0	27·0, 65·5	0·2	0·2, 1·0
P	<0·001***		<0·001***		0·07		0·001**		0·89		<0·001***		<0·001***		0·12	
BAZ status																
Thinness (*n*=37)	0·82	0·63, 0·95[a]	0·68	0·56, 0·77[a]	7·83	7·12, 9·11	0·05	0·03, 0·08	0·24	0·18, 0·38[a,b]	124·0	117·5, 129·0[a]	31·0	18·0, 57·0[a]	0·2	0·2, 1·4[a]
Overweight/obese (*n*=120)	0·96	0·79, 1·21[b]	0·87	0·71, 1·05[b]	7·67	6·61, 9·37	0·06	0·04, 0·09	0·24	0·16, 0·36[a]	133·5	125·0, 138·0[b]	53·0	32·5, 84·8[b]	1·2	0·2, 4·2[b]
Normal (*n*=619)	0·88	0·74, 1·02[a]	0·75	0·63, 0·89[a]	7·81	6·82, 9·01	0·06	0·04, 0·09	0·30	0·20, 0·43[b]	126·0	118·0, 132·0[a]	39·0	23·0, 60·0[a]	0·2	0·2, 0·6[a]
P	<0·001†††		<0·001†††		0·94		0·23		0·001††		<0·001†††		<0·001†††		<0·001†††	
WAZ status‡																
Underweight (*n*=168)	0·82	0·66, 0·98	0·67	0·56, 0·82	7·93	6·90, 9·17	0·05	0·03, 0·08	0·26	0·19, 0·39	123·5	113·3, 128·0	30·5	19·0, 53·0	0·2	0·2, 0·7
Normal (*n*=383)	0·87	0·75, 1·02	0·76	0·63, 0·89	7·71	6·65, 8·97	0·06	0·04, 0·09	0·28	0·19, 0·39	126·0	118·0, 133·0	45·0	27·0, 66·0	0·2	0·2, 1·1
P	0·003**		<0·001***		0·21		0·02*		0·51		<0·001***		<0·001***		0·06	

RBP, retinol-binding protein; hs-CRP, high-sensitivity C-reactive protein; P25, 25th percentile; P75, 75th percentile; HAZ, height-for-age z-score; BAZ, BMI-for-age z-score; WAZ, weight-for-age z-score.
Significant difference based on Mann–Whitney U test: *$P < 0·05$; **$P < 0·01$; ***$P < 0·001$.
Significant difference based on Kruskal–Wallis H test: †$P < 0·05$; ††$P < 0·01$; †††$P < 0·001$.
Significant difference based on $\chi 2$ test: †P < 0·05; ††P < 0·01; †††P < 0·001.
Different alphabets in the same column within each variable indicate significant statistical differences ($P < 0·05$, Dunn's multiple comparison test).
‡ Only included children aged ≤ 10 years old (*n*=551).

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among stunted and underweight children. On the other hand, overweight children were found to have higher levels of retinol (0·96 µmol/l (P25:0·79, P75:1·21)), RBP (0·87 µmol/l (P25:0·71, P75:1·05)), Hb (133·5 g/l (P25:125·0, P75:138·0)), ferritin (53·0 µg/l (P25:32·5, P75:84·8)) and hs-CRP (1·2 mg/l (P25:0·2, P75:4·2)) compared with both thin and normal children.

Potential factors associated with stunting

Given that stunting was one of the most prevalent malnutrition problems, the associations between stunting with other variables were further analysed and shown in Table 5. Univariate logistic regression revealed that OA schoolchildren (COR: 6·1 (95 % CI 4·1, 9·0), P = <0·001), monthly household income <RM500 (COR: 2·5 (95 % CI 1·2, 5·0), P = 0·009), deficiency in retinol level (COR: 2·9 (95 % CI 1·8, 4·7), P = <0·001), marginal deficiency in retinol level (COR: 2·0 (95 % CI 1·3, 3·0), P = 0·001), deficiency in RBP level (COR: 2·9 (95 % CI 1·7, 5·1), P = <0·001), marginal deficiency in RBP level (COR: 2·0 (95 % CI 1·1, 3·4), P = 0·014), anaemia (COR: 2·2 (95 % CI 1·5, 3·3), P = <0·001), ID (COR: 2·4 (95 % CI 1·6, 3·7), P = <0·001) and IDA (COR: 3·6 (95 % CI 1·9, 6·6), P = <0·001) were significantly associated with stunting. The final multivariate analysis indicated that only OA schoolchildren (adjusted OR: 6·1 (95 % CI 4·1, 9·0), P = <0·001) and IDA (adjusted OR: 3·6 (95 % CI 1·9, 6·6), P = <0·001) retained as significant predictors for stunting among the children (goodness of fit: $\chi^2 = 0{\cdot}683$ ($df = 2$); $P = 0{\cdot}71$).

Discussion

This study depicts a high level of malnutrition (53·4 %) in primary schoolchildren living in rural areas of Malaysia. Our results simultaneously demonstrate the coexistence of underweight, stunting, thinness, overweight and obese children in rural areas of Malaysia, which is a common and significant problem in low- and middle-income countries and is described as a double burden of malnutrition[26]. Based on the recent NHMS 2019, the prevalence of stunting (17·1 %) and underweight (14·2 %) reported among children 5–17 years living in rural areas was about three times lower than our current findings. On the other hand, NHMS 2019 reported a higher prevalence of overweight (13·7 %), obesity (13·2 %) and thinness (11·2 %) compared with the prevalence reported in this study[4]. Another earlier study by Poh *et al.*[10] also demonstrated a lower prevalence of stunting (7·3 %) and higher prevalence of overweight (12·6 %), obesity (13·0 %) and thinness (9·3 %) among rural children aged 7–12 years as compared with our present study outcomes. The

Table 5. Univariate and multivariate logistic regression models for determination of factors associated with stunting (Odds ratios and 95 % confidence intervals, numbers and percentages, *n*=776)

				Univariate analysis			Multivariate analysis		
	n	*n*	%	Crude OR	95 % CI	*P*	Adjusted OR	95 % CI	*P*
Sex									
Boys	379	136	35·9	1·1	0·8, 1·5	0·58			
Girls	397	135	34·0	1					
Age group									
<10 years old	458	152	33·2	0·8	0·6, 1·1	0·22			
≥ 10 years old	318	119	37·4	1					
School category									
Orang Asli School	497	235	47·3	6·1	4·1 – 9·0	<0·001***	5·6	3·8, 8·4	<0·001***
Non-Orang Asli School	279	36	12·9	1			1		
Monthly household income									
<RM 500	715	257	35·9	2·5	1·2, 5·0	0·009**			
≥ RM 500	54	10	18·5	1					
Retinol level									
Deficiency (<0·70 µmol/l)	160	73	45·6	2·9	1·8, 4·7	<0·001***			
Marginal deficiency (0·70–<1·05 µmol/l)	441	159	36·1	2·0	1·3, 3·0	0·001**			
Sufficient (≥ 1·05 µmol/l)	175	39	22·3	1					
RBP level									
Deficiency (<0·70 µmol/l)	309	130	42·1	2·9	1·7, 5·1	<0·001***			
Marginal deficiency (0·70–<1·05 µmol/l)	371	122	32·9	2·0	1·1, 3·4	0·01*			
Sufficient (≥ 1·05 µmol/l)	96	19	19·8	1					
Anaemia									
Yes (Hb <115 g/l)	116	59	50·9	2·2	1·5, 3·3	<0·001***			
No (Hb ≥ 115 g/l)	660	212	32·1	1					
Iron deficiency									
Yes (ferritin <15 µg/l)	99	53	53·5	2·4	1·6, 3·7	<0·001***			
No (ferritin ≥ 15 µg/l)	677	218	32·2	1					
Iron-deficiency anaemia									
Yes (Hb <115 g/l and ferritin <15 µg/l)	47	30	63·8	3·6	1·9, 6·6	<0·001***	2·3	1·2, 4·3	0·01*
No (Hb ≥ 115 g/l or ferritin ≥ 15 µg/l)	729	241	33·1	1			1		
High inflammation									
Yes (hs-CRP > 5·0 mg/l)	76	20	26·3	0·6	0·4, 1·1	0·10			
No (hs-CRP ≤ 5·0 mg/l)	700	251	35·9	1					

RBP, retinol-binding protein; hs-CRP, high-sensitivity C-reactive protein.
Significant difference: *P < 0·05; **P < 0·01; ***P < 0·001.

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differences could be due to the different sampling protocols, population type, geographical areas, SES and age category (inclusion of pre-school age and adolescent children in the previous surveys).

Our study demonstrated a higher prevalence of overall malnutrition and undernutrition (stunting and underweight) among OA schoolchildren, while a lower prevalence of overnutrition (overweight and obesity) compared with NOA schoolchildren, with no difference observed between sex and age groups. Comparable findings were reported by previous local studies[27,28]. Nevertheless, the high prevalence of undernutrition among the OA children in this study reflects the persistence of poor nutrition among OA children, as they are significantly associated with socio-economic disadvantage, which leads to food insecurity and compromised growth and development[28].

Based on SEANUTS Malaysia, VAD is considered a mild public health problem among Malaysian children as only a tiny percentage of children (4·4 %) were observed to have VAD with a higher prevalence in rural areas (6·4 %)[10]. However, the present study revealed a higher prevalence of VAD among rural schoolchildren at 20·6 % based on retinol concentration and 39·8 % based on RBP. Based on WHO definition (29), VAD among our children population is considered a severe public health problem, whereby more than ≥ 20 % of them were diagnosed with retinol concentration <0·7 μmol/l. The notable variations in the VAD prevalence reported could be due to the differences in population, ethnicity and geographical areas covered, as SEANUTS Malaysia does not include OA population.

The prevalence of VAD based on retinol level among OA schoolchildren in the present study was similar to findings reported by previous local studies[14,30]. In addition, Ngah *et al.*[31] reported a high occurrence of ocular manifestation of VAD at 64·3 % among 213 OA children aged under 15 years old in an OA settlement at Pos Piah, Perak. However, retinol concentration, which is more commonly used in vitamin A status assessment, was not being measured in the study mentioned above. In the present study, compared with NOA schoolchildren, OA schoolchildren exhibited a higher prevalence of VAD. Poor dietary intake/food availability, dietary, cultural behaviour and relatively high intestinal parasitic infections in OA schoolchildren due to poor hygiene practices and inadequate sanitation may contribute to this difference in prevalence[14,30,32].

We also found that retinol and RBP levels increased with age, while VAD decreased with age. These findings were consistent with those found in previous studies[10,33–36]. It is possibly due to physical growth, lower dietary diversification and higher risk of infections among the younger age group[33]. Another possible reason could be the use of a single cut-off point of VAD status for children, which might overestimate VAD status among younger children who possibly have lower physiological vitamin A levels[35].

The present study demonstrated that the prevalence of anaemia and ID was at 14·9 and 12·8%, respectively, which is in line with the classification of anaemia as a mild public health problem (5·0–19·9 %) based on WHO cut-off[23]. Higher rates were reported in other local studies[11]. Meanwhile, Poh *et al.*[10] reported a lower prevalence of anaemia (5·1%) and ID (2·2%) among Malaysian rural children aged 7–12 years old. However, among the currently studied OA schoolchildren, the prevalence of anaemia, ID and IDA was relatively lower than the range of prevalence reported in previous local studies conducted among OA children[12,13,37–39]. This study also observed that the OA schoolchildren exhibited significantly higher anaemia, ID and IDA levels with lower Hb and ferritin concentrations than NOA schoolchildren. Based on findings from previous studies, recurrent infections, in particular soil-transmitted helminths, low dietary intake of Fe and poor SES among OA schoolchildren could be the contributing factors[11,12].

In addition, we found that older children exhibited higher Hb levels and a lower prevalence of anaemia, which is following previous findings[40–42]. The current observation could be partly explained by the significantly lower levels of vitamin A in children aged <10 years, as vitamin A plays a vital role in modulating Fe metabolism and erythropoiesis[43]. By age group, our study showed that both α- and β-carotene levels were higher among children aged ≥ 10 years. This scenario is consistent with findings reported by Gregory *et al.*[44], where β-carotene levels increased with age in both sexes among British children. On the contrary, α- and β-carotene levels were inversely related to age among US children and adolescents aged 6–16 years old[45]. The reason for these differences in findings is unclear, but we speculate that it could be due to the diversity of plant-based foods consumption in different geographical locations.

In the present study, we observed that OA schoolchildren exhibited higher levels of α-tocopherol and β-carotene and lower α-carotene levels than NOA schoolchildren. The cause of this outcome is uncertain as diet consumption data are not collected in this study. Nevertheless, the higher level of β-carotene among OA schoolchildren may indicate higher consumption of carotenoid-containing foods as the proportion of β-carotene in plant sources and their theoretical conversion efficacy to vitamin A (retinol) are higher than α-carotene[46].

In the comparative analysis, both retinol and RBP levels were also found to be significantly lower among stunted and underweight children while higher among overweight/obese children. These findings are in agreement with previous studies that link VAD with a higher risk of stunting and underweight among children, which may reflect the impact of VAD for a prolonged period on growth retardation[47,48]. In addition, similar to our findings, previous studies have shown that RBP levels were higher among overweight and obese groups, which indicates RBP levels are associated with a degree of adiposity[49,50]. We also observed that Hb levels were significantly lower among stunted and underweight children than overweight/obese children. Previous studies have also shown an association between anaemia with undernourished children[37,51,52]. A meta-analysis conducted among pre-school-age children also demonstrated that anaemia was associated with stunting and being underweight in most studies[53].

A reduced level of ferritin was also observed among stunted and underweight children. Both ferritin and hs-CRP levels were also found to be elevated among overweight/obese children. Numerous studies have reported elevated inflammatory markers

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among overweight and obese people[54–56]. Besides, the present study findings are similar to findings reported by Khan *et al.*[57], where ferritin and hs-CRP were found positively associated with BMI. These findings support the evidence on elevated ferritin levels in the obesity-related inflammatory process as serum ferritin is an acute-phase reactant protein that is similar to hs-CRP, which increases in response to inflammation due to increased cytokine levels[57,58].

Further findings showed that stunting problem was associated with OA school and IDA. Stunting is known to occur concurrently with ID and anaemia, which is associated with poor SES[59]. It is reported that individuals with poor SES are more likely to have low-quality diets which are less adherent to dietary guidelines, thus leading to their poor health status[60]. In this study, majority (93 %) of the current population have low monthly household income (<RM500) which could be one of the contributing factors for the occurrence of IDA among the children, hence increasing the odds of being stunted. IDA can be due to the low intake of Fe from animal food sources, especially among populations consuming mainly plant-based diets[61]. It was reported that OA children have low dietary diversity and meat consumption, which could be the causative factor for IDA resulting in higher risk of stunting among them[62].

Most of the previous studies that discussed malnutrition among OA children targeted pre-school-age children, mainly from single education institutions or villages[39,63–65]. To our knowledge, this is the first study to report malnutrition levels based on both anthropometric assessments and biochemical assessments among children from multiple OA schools and their comparisons with children from NOA schools in Malaysia. The present study provides valuable findings on the nutritional status of Malaysian children from rural areas.

A limitation of this study is the unbalanced sample size between the OA school group and NOA school group, whereby the number of OA schoolchildren included in the data analysis was two times the number of NOA schoolchildren. Nevertheless, non-parametric tests and χ^2 tests were used as these tests do not require equal sample size. It is also acknowledged that the selection of schools with generally poor SES and exclusion of schools not accessible by road transportation may create sampling bias, but it is inevitable as most of the rural OA schools have generally poor SES and accessibility by road transportation is crucial to process blood samples timely to ensure the good quality of the samples. Additionally, since our study involved a vulnerable group, the difficulty of collecting blood samples from the children led to insufficient blood volume collected. Therefore, we had to omit them from the data analysis. However, the sample size was still sufficient despite dropouts due to incomplete samples or data collected. In addition to what we have measured (retinol, RBP and ferritin levels) which could be impacted by inflammatory status, both α-1-acid glycoprotein and CRP have also been shown to correct ferritin levels in response to inflammation[66,67]. However, the limitation of the current study is that α-1-acid glycoprotein was not measured and therefore adjusted values of the ferritin for inflammation could not be determined otherwise in this aspect. Malnutrition determinants such as dietary pattern, access to food sources, physical activity and infection status are also essential factors in the study. Nevertheless, due to limited resources, these data were not collected in the study, and further research is warranted to enhance the understandings of the current population.

In conclusion, malnutrition is still highly prevalent among primary schoolchildren living in rural areas of Malaysia. The present study revealed that the prevalences of malnutrition, VAD, anaemia, ID, IDA and elevated inflammation were higher among OA schoolchildren than NOA schoolchildren. In addition, higher occurrences of VAD and anaemia were found among children aged below 10 years. Besides, children with undernutrition exhibited lower retinol, RBP, α-carotene, ferritin and Hb. On the other hand, overweight/obesity status was linked to elevated hs-CRP levels. It was also found that children from OA schools and IDA were associated with stunting. The findings of this study provided valuable information for public health authorities to re-evaluate the existing measures in addressing malnutrition among rural primary schoolchildren, especially those from OA schools and younger age groups.

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The authors declare that they have no known conflicting interests.

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