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Nutritional status and dietary fatty acid intake among children from low-income households in Sabah: A cross-sectional study

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A R T I C L E I N F O

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A B S T R A C T

Objectives: This study aimed to assess the nutritional status and dietary fatty acid intake among children from low-income households in Sabah, Malaysia.

Methods: This cross-sectional study was conducted from December 2022 to February 2023 in Kota Kinabalu and Tawau. A total of 182 children aged 5–12 years from low-income households (less than RM 4850 per month) were recruited. Anthropometric measurements included body weight, height, and body mass index. Dietary intakes were assessed using a 24-h diet recall and the fatty acid (FA) intakes were analyzed using a database with FA content for local foods.

Results: The mean age of children was 8.8 ± 1.8 years, with a majority being girls (53.8%) and of Bajau ethnicity (53.3%). Based on the anthropometric measurements, 16.5% of children were stunted, 7.1% were thin, and 21.4% were overweight or obese. Intakes of total fat, saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), and *trans* fatty acids as a percentage of total energy were 29.3%, 12.3%, 12.6%, 4.0%, and 0.05%, respectively. 77.5% of children exceeded the recommendation for SFA and 63.2% of children did not meet the recommendation for *n*-3 PUFA. All children did not meet the recommendation for α-linolenic. Children from Tawau had greater consumption of *n*-3 PUFA ($p < 0.001$) while children from Kota Kinabalu had greater intakes of total fat ($p = 0.020$), MUFA ($p = 0.005$), *n*-6 PUFA ($p = 0.015$), and *trans* fatty acid ($p = 0.001$). None of the dietary fatty acids was associated with anthropometric indices.

Conclusions: There was a high prevalence of stunting and overweight or obesity among children from low-income households in Sabah. Most of the children failed to meet the recommendations for SFA and *n*-3 PUFAs. These findings indicate a compelling need for the implementation of nutritional strategies to enhance adherence to dietary recommendations for fatty acids.

1. Introduction

The double burden of malnutrition, encompassing both undernutrition (wasting, stunting, and underweight) and overnutrition (overweight and obese) is a global public health concern that affects the well-being of young children [1]. It is estimated that 22.0% of children under 5 years worldwide suffer from stunting, while 6.7% are affected by wasting [2]. For children aged 6–12 years, the prevalence of stunting is also alarmingly high, reported to be at 57% [3], while 5.2% of children in this age group were reported to be underweight [4]. Concurrently, childhood obesity, the other extreme of the malnutrition coin, continues to escalate worldwide. It is estimated that 206 million children and adolescents aged 5–19 years will be affected by obesity in 2025. The high prevalence of childhood obesity is no longer confined to high-income countries, both low- and middle-income countries also experience a significant surge in the prevalence of obesity [5]. In the Malaysian context, the National Health and Morbidity Survey (NHMS) 2019 reported that the prevalence of underweight among children and adolescents aged 5–17 years was 15.4%, and it was more prevalent among girls and children from urban areas. In addition, 12.7% of them were stunted, particularly among children from rural areas and with low household incomes. In contrast, 15.0% of children and adolescents aged 5–17 years were overweight while 14.8% of them were obese, with these conditions being more prevalent among boys and those from low-income households [6].

Nutrition plays a pivotal role in promoting optimal growth and

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cognitive development during early childhood and poor nutrition during this period is associated with increased risks of morbidity and mortality later in life [7]. Dietary fatty acids are a dense energy source and play a crucial role in meeting the high energy needs for rapid growth and healthy development during childhood [8]. Polyunsaturated fatty acids (PUFAs), including both *n*-3 PUFAs and *n*-6 PUFAs, are involved in various physiological functions during childhood. These fatty acids are key components in cell membrane formation and function, and they contribute to visual and neural development, as well as immune function [9]. Given that the brain, retina, and neural tissues are notably rich in PUFAs, adequate intakes are essential for the development brain and neurological system, photoreception, and reproductive system in children [10,11]. In addition, both *n*-3 PUFAs and *n*-6 PUFAs have cardioprotective effects. It has been shown that the replacement of saturated fatty acids (SFA) with PUFAs was associated with reduced blood pressure, total cholesterol, and low-density lipoprotein cholesterol levels among children [12,13].

In epidemiological research, dietary fatty acid intake in children is commonly assessed using various dietary assessment tools, including 24-h dietary recall, diet records, and food frequency questionnaires [14], while fatty acid biomarkers obtained from blood and adipose tissue can also serve as objective markers that reflect habitual dietary fatty acid intakes [15]. A systematic review of 65 studies conducted in 33 countries found that the total fat intake among younger children aged between 1 and 7 years was low. It was also reported that the dietary SFA intake exceeded the recommendation while *n*-3 PUFA intakes, especially DHA, were suboptimal [16]. Similarly, a cross-sectional study conducted in India reported that dietary *n*-3 PUFA intakes were low among school children aged between 7 and 13 years [17]. Despite the significance of dietary fatty acid intake in childhood development, research is scarce on this subject in Malaysia, particularly in the state of Sabah. Tan et al. [18] highlighted a critical trend in Sabah, revealing a higher prevalence of malnutrition among children under five years in the interior districts compared to the national average, with the prevalence rate of underweight, stunting, and wasting at 20.2%, 29.2%, and 5.6%, respectively. Meanwhile, the prevalence of overweight and obese was 5.0%. However, the scope of this study was limited to children below five years, leaving a gap in understanding the nutritional status of older children. Therefore, the present study aimed to fill this gap by determining the nutritional status and dietary fatty acid intake among children aged 5–12 years in Sabah, particularly focusing on those from low-income households. To our knowledge, this study represents the first comprehensive analysis of dietary fatty acid intake among children in Malaysia.

2. Methods and materials

2.1. Study design

This was a cross-sectional study conducted from December 2022 to February 2023 in Kota Kinabalu and Tawau, Sabah, Malaysia. The sample size was calculated using a single proportional formula [19]. Based on the reported prevalence of stunting of 12.7% among children aged 5–17 years from the NHMS 2019 [6] and factoring a 5% margin of error, the required sample size was determined to be 170 children. Participants were recruited via convenience sampling from a preschool (Pra-Sekolah SK Likas) and two primary schools (SK Likas and SK Batu 4 Jalan Apas). This study has received ethical approval from the Medical Ethical Committee of Universiti Malaysia Sabah [JKEtika 1/23 (1)], and written informed consent was obtained from the children's parents or guardians.

2.2. Participants

Children aged 5–12 years from low-income households in Sabah were included in this study. Low-income households were defined as having a monthly income of less than RM4,850, aligned with the B40 category [20]. In Malaysia, B40 is a socioeconomic classification that refers to households with income at the bottom 40% of the country. These households were often the target of governmental aid programs and subsidy policies aimed at poverty alleviation and improvement of living conditions. We excluded children with mental disorders, physical disability, congenital problems, or chronic illnesses as well as those who were not able to speak, read, and understand Bahasa Malaysia or English.

2.3. Data collection procedures

Anthropometric measurements were performed by researchers following standard protocols. Body weight was measured using a calibrated digital weighing scale (Omron HBF-375, Omron, Japan) in kilograms to the nearest 0.1 kg. Children stood on the center of the weighing scale in lightweight clothing and bare feet and remained motionless until the measurement was obtained. Height was measured using a portable stadiometer (Seca 213, Seca GmbH, Germany) in cm to the nearest 0.1 cm. Children stood up straight with bare feet that were kept together, with buttocks, shoulder blades, and heels touching the stadiometer. The head was level with a horizontal Frankfurt plane. All measurements were taken twice, and means were calculated. Body mass index (BMI) was derived using the formula weight (kg)/height^2 (m^2). These anthropometric indices were classified using the WHO Growth Standards reference for 5–19 years. Stunting was defined as the z-score for height-for-age below −2 standard deviations (SD). Based on the BMI-for-age, thinness was defined as a z-score below −2 SD, overweight was defined as a z-score above +1 SD, and obese was defined as a z-score above +2 SD.

Dietary intake was assessed using the 24-h dietary recall method conducted in face-to-face interviews with parents or guardians as proxies. Standard household measurement tools were used for the portion size estimation. Foods and beverages in household units were converted into absolute weight in grams or millimeters for nutrient analysis using the Nutritionist Pro software (Axxya Systems LLC, USA), referencing Malaysian [21] and Singaporean [22] food composition databases to derive total energy, carbohydrate, protein, and fat intakes. To ensure the accuracy of dietary reporting, Goldberg's cut-off was used to identify potential under-reporters and over-reporters [23]. Basal metabolic rates were estimated using the predictive equations by Schofield [24] and Poh et al. [25]. An energy intake to basal metabolic rate ratio within the range of 1.0–2.0 was considered acceptable, while ratios below 1.0 indicated under-reporting, and ratios above 2.0 indicated over-reporting [26].

Since both Malaysian and Singaporean food composition databases lacked individual fatty acid content, a database containing fatty acid compositions of local foods was referred [27]. Dietary fatty acid intakes were then compared against established recommendations from Recommended Nutrient Intakes 2017 [28] and the European Food Safety Authority [29]. The recommended intake levels were 25–35% of total energy (EN) for total fat, ≤10% EN for SFA, 12–15% EN for monounsaturated fatty acid (MUFA), 3–7% EN for *n*-6 PUFAs, >4% EN for linoleic acid (LA), 0.3–1.2% EN for *n*-3 PUFAs, >0.5% EN for α-linolenic acid (ALA), >250 mg/day for the sum of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), less than 1% EN for *trans* fatty acid (TFA). Although there were ranges provided for MUFA, *n*-3 PUFA, and *n*-6 PUFA, this study categorized the intake of these fatty acids as either meeting or not meeting the lower recommended limits, as exceeding these ranges is not known to pose adverse health effects.

2.4. Statistical analyses

Kolmogorov-Smirnov test was used to assess the normality of continuous variables. Continuous variables with normal distribution were presented as mean ± SD while skewed variables were presented as median and interquartile range (IQR). Categorical variables were presented as frequency (percentage). Independent *t*-test and Mann-Whitney test were used to compare nutrient intakes between children from Kota Kinabalu and Tawau. Partial correlation adjusted with age was used to assess the association between nutrient intakes and anthropometric indices. All analyses were computed using SPSS version 29.0 (IBM, Chicago, IL, USA). Statistical significance was set at $p < 0.05$ for all evaluated parameters.

3. Results

The final analyses included 182 children aged from 5 to 12 years, and their characteristics are presented in Table 1. The mean age was 8.8 ± 1.8 years, the majority being girls (53.8%) and Bajau ethnicity (53.3%). Most children's parents were married (85.7%). Most of the children's fathers had none or primary school education level (53.1%) and were employed (84.6%), while most of the children's mothers had none or primary school education level (51.1%) and were unemployed (75.8%). A majority of the children had a family household size between 3 and 4 members. The children's median weight was 24.1 (IQR: 10.8) kg, and the mean height was 126 ± 11.4 cm. Theie median BMI was 15.5 (IQR: 3.1) kg/m^2. Fig. 1 shows the children's nutritional status based on height-for-age and BMI-for-age. A majority (83.5%) of the children had a normal height while 16.5% of them were stunted. Similarly, most (71.4%) of the children had a normal BMI, while 7.1% of them were categorized as thin, and 21.4% of them were overweight or obese.

Fig. 2 illustrates dietary intakes of energy, macronutrients, and fatty acids against the recommendations. A majority of the children achieved the recommendations for energy (57.1%), carbohydrate (64.8%), protein (99.5%), total fat (57.1%), MUFA (64.8%), and *n*-6 PUFA (71.4%). In contrast, 77.5% of the children exceeded the SFA intake, and most of them also did not meet the dietary recommendation for *n*-3 PUFA (63.2%) and EPA + DHA (57.7%). Notably, none of the children achieved the recommended intake for ALA, although the dietary TFA intake of all children remained within the recommended limit. Table 2 compares the dietary intake of energy, macronutrients, and fatty acids between children from Kota Kinabalu and Tawau. Children from Tawau had greater consumption of energy ($p < 0.001$), carbohydrate ($p < 0.001$), protein ($p < 0.001$), *n*-3 PUFA ($p < 0.001$), α-linolenic acid ($p = 0.049$), EPA ($p < 0.001$), DHA ($p < 0.001$). Contrarily, children from Kota Kinabalu had greater intakes of total fat ($p = 0.020$), stearic acid ($p = 0.003$), MUFA ($p = 0.005$), oleic acid ($p = 0.004$), *n*-6 PUFA ($p = 0.015$), linoleic acid ($p = 0.007$), and *trans* fatty acid ($p = 0.001$). There were no significant differences in the intakes of SFA ($p = 0.180$), lauric acid ($p = 0.215$), myristic acid ($p = 0.413$), palmitic acid ($p = 0.207$), and total PUFA ($p = 0.203$) between children from these two locations. None of the children reported consuming any lipid-based dietary supplements.

The association between anthropometric indices and the intake of energy, macronutrients, and fatty acids is shown in Table 3. Positive associations were observed between total energy and weight ($r = 0.370$), height ($r = 0.159$), and BMI ($r = 0.382$). However, the intake of carbohydrate, protein, total fat, and all fatty acids were not significantly associated (all *p*-values <0.05) with any of the anthropometric indices.

Table 1
Characteristics of children and their parents ($n = 182$).

Characteristics	*n* (%)	Mean ± SD/Median (IQR)
Age (year)		8.8 ± 1.8
Sex		
Boys	84 (46.2)	
Girls	98 (53.8)	
Ethnicity		
Bajau	97 (53.3)	
Malay	9 (4.9)	
Dusun	8 (4.4)	
Murut	7 (3.8)	
Kedayan	4 (2.2)	
Others	57 (31.3)	
Parental marital status		
Married	156 (85.7)	
Widowed	14 (7.7)	
Divorced	12 (6.6)	
Fathers' education level[a]		
None/primary	94 (53.1)	
Secondary	69 (39.4)	
Tertiary	13 (7.4)	
Mothers' education level		
None/primary	93 (51.1)	
Secondary	32 (39.6)	
Tertiary	17 (9.3)	
Fathers' employment status[a]		
Employed	148 (84.6)	
Unemployed/retired	27 (15.4)	
Mothers' employment status		
Employed	44 (24.4)	
Unemployed/retired	138 (75.8)	
Household size		
1–2	39 (21.4)	
3–4	92 (50.5)	
≥5	51 (28.1)	
Weight (kg)		24.1 (10.8)[b]
Height (cm)		126 ± 11.4
BMI (kg/m^2)		15.5 (3.1)[b]

[a] $n = 175$ because the information on fathers was not available for 7 participants.
[b] data is skewed to the right.

4. Discussion

In the present study, there was a high prevalence of both overweight or obesity and stunting among children from low-income households in Sabah. This phenomenon, where undernutrition coexists with overnutrition is reflective of the dual burden of malnutrition trend in developing countries. The prevalence of thinness and stunting observed in this study was higher than the prevalence reported by the NHMS 2019 for children aged 5–17 years in Sabah [6]. Similarly, a nationally presentative study carried out in peninsular also reported a lower prevalence of stunting and overweight/obesity among children aged 6 months to 12 years, at 8.9% and 18.0%, respectively [30], compared to our findings. One possible explanation was the inclusion of only children from low-income households in our study, since children from low socioeconomic groups are known to have a higher risk of stunting, primarily due to factors such as low diet quality, poor living environment and sanitation, and a greater susceptibility to infections [31]. Conversely, low socioeconomic status is also associated with obesity. A meta-analysis indicates that children aged 0–15 years from low socioeconomic strata have a 10% higher risk of being overweight and a 41% higher risk of being obese. The potential underlying mechanisms for this include diets that are low in cost and nutritional values but energy-dense, limited opportunities for physical activity and sports, and lack of awareness or resources for weight management [32]. Stunting has profound social, human, and economic consequences, such as hindered physical and cognitive development, poor educational outcomes, and reduced workforce productivity, leading to per capita income losses in the region [33]. Likewise, childhood obesity imposes significant personal, societal, and economic burdens, including direct medical expenses and indirect costs like caregiver productivity loss due to increased absenteeism. Further, childhood obesity may persist through adulthood, which leads to lifelong financial burden due to obesity-related health complications [34].

A majority of the children in the present study failed to meet the dietary recommendation for certain fatty acids, particularly SFA and *n*-3 PUFAs. This pattern is consistent with the finding from a global review that reported that SFA intake among children from predominantly developed countries was generally above the recommendation, while *n*-3 PUFA intakes were suboptimal [16]. In our study, about half of the

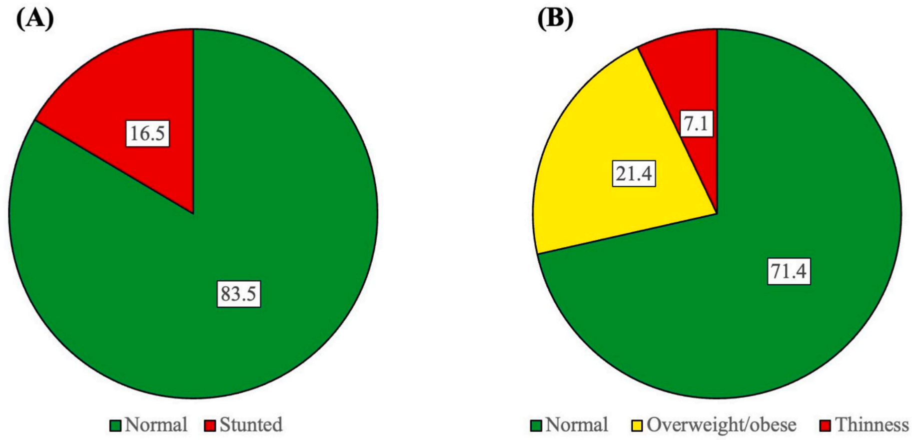

Fig. 1. Nutritional status of children based on height-for-age (A) and BMI-for-age (B).

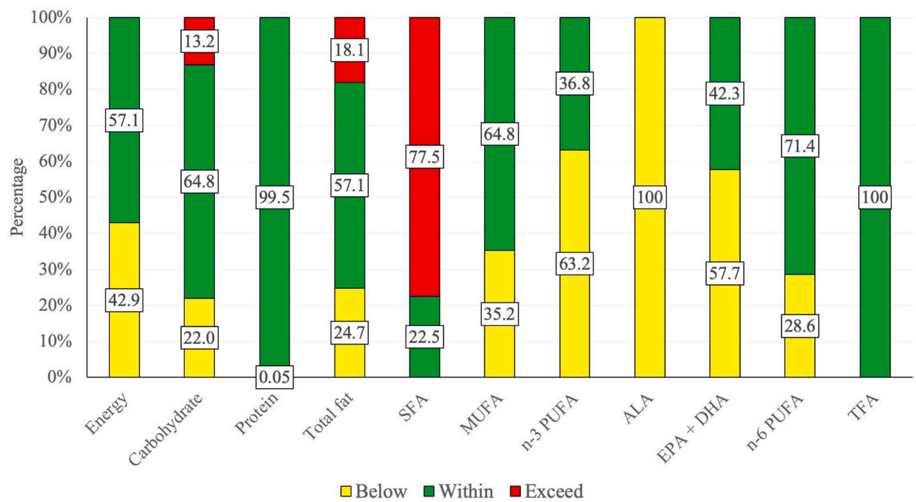

Fig. 2. Comparison of children's dietary intake against recommended guidelines. Abbreviations: ALA, α-linolenic acid; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; SFA, saturated fatty acid; TFA, *trans* fatty acid.

children met the recommended total fat intake of 25–35% EN. However, almost four out of five children exceeded the SFA intake of 10% EN. A similar finding was reported in a separate study conducted at Klang Valley, Malaysia, where it was found that 63% of children aged 7–10 years had SFA intakes exceeding 10% EN [35]. The World Health Organization has issued a recommendation for children to reduce their SFA intakes to 10% EN. This recommendation is supported by randomized controlled trials conducted in children that showed SFA reductions resulted in lower levels of low-density lipoprotein cholesterol and blood pressure [36]. The high SFA intake among children in Malaysia is likely attributed to the prevalent use of palm oil, which contains almost 50% of SFA. A study showed that 83.9% of the urban adult population in Malaysia were palm oil users, resulting in an average SFA intake of 14.1% EN [37]. The Malaysian Dietary Guidelines 2020 recommend blending palm oil with oils rich in *n*-6 PUFAs (such as soybean oil, corn oil, and sunflower oil) as a strategy to reduce the SFA intake at a population level [38]. However, these alternatives are typically more expensive and may not be readily affordable for low-income households.

On the other hand, there was a concerning trend, in which the intake of *n*-3 PUFAs among children was suboptimal, with none meeting the recommendation for ALA. Although deficiencies are rare, they can lead to reduced growth rates in children, dry scaly rash, hair loss, impaired wound healing, and increased susceptibility to infections [39]. While it is true that foods rich in *n*-3 PUFAs such as walnuts, flaxseeds, and salmon, tend to be more costly, socioeconomic factors alone do not fully account for the suboptimal intake of *n*-3 PUFAs in this population. Parasannanavar et al. [17] found no significant difference in *n*-3 PUFA intakes among children aged 7–13 years from various socioeconomic backgrounds. Therefore, further research is required to explore other factors such as parental knowledge and awareness, as well as the accessibility of *n*-3 PUFA-rich foods in influencing *n*-3 PUFA intakes among children. Local marine fishes such as anchovies (*bilis*), Indian mackeral (*kembong*), toli shad (*terubuk*), are affordable sources of marine *n*-3 PUFAs [40] while soybean products such as tofu and tempeh can be a great source *n*-3 and *n*-6 PUFAs [41]. It is important for nutrition practitioners to educate the public about the appropriate preparation method because high temperature cooking methods such as deep-frying can significantly reduce the content of *n*-3 PUFAs [42]. Interestingly, the present study also highlighted regional dietary differences in fatty acid intakes between children from Tawau and Kota Kinabalu. Children from Tawau consumed more protein and *n*-3 PUFAs compared to their counterparts in Kota Kinabalu. This variation can be attributed to the geographical location in Tawau which has greater access to marine resources, particularly fish which is a rich source of both protein and *n*-3 PUFAs. In addition, the majority of children in Tawau belong to the Bajau community, known to traditionally reside in coastal regions. It has been shown that coastal indigenous communities tend to consume more seafood than the national average [43].

Table 2
Energy, macronutrient, and fatty acid intakes among children in Kota Kinabalu and Tawau.

Nutrients	All (n = 182)	Kota Kinabalu (n = 99)	Tawau (n = 83)	p-value
Energy (kcal)	1567 ± 364	1460 ± 276	1694 ± 415	<0.001
Carbohydrate (g)	218 ± 57	203 ± 43	235 ± 67	<0.001
Protein (g)	52.3 (26.7)	48.9 (21.9)	61.0 (27.9)	<0.001[a]
Total fat (g)	51.1 ± 16.4	49.6 ± 15.4	52.9 ± 17.5	0.183
Total fat (%EN)	29.3 ± 6.8	30.4 ± 7.2	28.1 ± 6.2	0.020
SFA (%EN)	12.3 ± 3.9	12.6 ± 2.9	12.0 ± 2.9	0.180
Lauric acid (%EN)	0.36 (0.38)	0.48 (0.38)	0.44 (0.34)	0.215[a]
Myristic acid (%EN)	0.47 (0.37)	0.52 (0.43)	0.58 (0.49)	0.413[a]
Palmitic acid (%EN)	9.5 ± 2.2	9.7 ± 2.3	9.3 ± 2.1	0.207
Stearic acid (%EN)	1.6 ± 0.5	1.7 ± 0.5	1.5 ± 0.5	0.003
MUFA (%EN)	12.6 ± 3.2	13.2 ± 3.4	11.9 ± 2.9	0.005
Oleic acid (%EN)	12.0 ± 3.1	12.6 ± 3.2	11.3 ± 2.8	0.004
Total PUFA (%EN)	4.0 ± 1.4	4.1 ± 1.2	3.9 ± 1.0	0.203
n-3 PUFA (%EN)	0.18 (0.39)	0.11 (0.22)	0.32 (0.50)	<0.001[a]
α-linolenic acid (%EN)	0.07 (0.07)	0.05 (0.06)	0.08 (0.07)	0.049[a]
EPA (mg)	56 (191)	17 (99)	156 (464)	<0.001[a]
EPA (%EN)	0.03 (0.13)	0.01 (0.06)	0.10 (0.24)	<0.001[a]
DHA (mg)	52 (347)	8 (166)	170 (358)	<0.001[a]
DHA (%EN)	0.03 (0.18)	0.01 (0.10)	0.10 (0.19)	<0.001[a]
n-6 PUFA (%EN)	3.7 ± 1.1	3.9 ± 1.2	3.5 ± 1.0	0.015
Linoleic acid (%EN)	3.5 ± 1.1	3.7 ± 1.1	3.3 ± 0.9	0.007
Trans fatty acid (%EN)	0.05 (0.06)	0.07 (0.06)	0.04 (0.04)	0.001[a]

Data is expressed as mean ± standard deviation or median (interquartile range).
Abbreviation: %EN, percent total energy; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; RNI, recommended nutrient intake; SFA, saturated fatty acid.
[a] Mann-Whitney test.

Our study has several limitations. Firstly, this study was confined to two districts in Sabah and focusing exclusively on children from low-income households, limits the generalizability of our findings to other regions in Malaysia or children from different socioeconomic backgrounds. Secondly, the use of a 24-h diet recall for assessing dietary intake is prone to recall bias and may not be able to accurately capture the variability in habitual dietary patterns. However, this approach was chosen based on considerations of feasibility and resource constraints, since the 24-h dietary recall is efficient in collecting dietary intake data and has minimal burden on participants, particularly in this study involving children. In addition, there is no validated food frequency questionnaire specifically designed to assess dietary fatty acids of our target population, and the procedure for obtaining fatty acid biomarkers as objective measure of fatty acid intake is considered invasive, particularly for children. Nevertheless, we have used the Goldberg ratio to mitigate this limitation by excluding potential mis-reporters, enhancing the reliability of our dietary data. Third, this study assessed the nutritional status based on solely anthropometric measurements. The inclusion of biochemical parameters or cognitive function assessment could provide deeper insights into the relationship between dietary fatty acid intake and health implications. Despite these limitations, this study offers a comprehensive analysis of the dietary fatty acid intake among children in Sabah, Malaysia, which is valuable information for public health authorities to design and implement nutritional interventions aimed to improve the nutritional status and adherence towards dietary fatty acid recommendations.

Table 3
Association between anthropometric indices and intakes of energy, macronutrients, and fatty acids.

Nutrients	Anthropometric indices		
	Weight (kg)	Height (cm)	BMI (kg/m^2)
Energy (kcal)	0.370*	0.159†	0.382*
Carbohydrate (%EN)	0.026	−0.055	0.042
Protein (%EN)	−0.004	0.011	−0.016
Total Fat (%EN)	−0.043	0.006	−0.044
SFA (%EN)	−0.072	−0.018	−0.070
MUFA (%EN)	0.007	0.008	0.018
PUFA (%EN)	0.028	0.071	0.022
n-3 PUFA (%EN)	−0.006	−0.010	−0.011
ALA (%EN)	0.011	0.042	0.009
EPA (%EN)	0.008	−0.007	0.001
DHA (%EN)	−0.020	−0.026	−0.022
n-6 PUFA (%EN)	0.030	0.076	0.026
LA (%EN)	0.029	0.078	0.025

Data was presented as partial correlation coefficients.
*p value < 0.001, †p value < 0.05.
Abbreviations: %EN, percent total energy; ALA, α-linolenic acid; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; LA, linoleic acid; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; SFA, saturated fatty acid; TFA, *trans* fatty acid.

5. Conclusions

In conclusion, there was a high prevalence of stunting and overweight or obesity among children from low-income households in Sabah. The dietary fatty acid intakes differed between children from Kota Kinabalu and Tawau. Most of the children failed to meet the recommendations for SFA and n-3 PUFAs. These findings indicate a compelling need for the implementation of nutritional strategies to enhance adherence to dietary recommendations for fatty acids. Future research should examine the relationship between dietary fatty acid intake and other health outcomes such as cognitive function and cardiometabolic parameters.

CRediT authorship contribution statement

Alice Chen: Writing – original draft, Investigation, Formal analysis, Data curation. **Nur Batrisyia Rafiz Azuan:** Writing – review & editing, Investigation, Formal analysis. **Nur'Ain Mardhiyah Harun:** Writing – review & editing, Investigation, Formal analysis. **Yasmin Beng Houi Ooi:** Writing – original draft, Investigation, Conceptualization. **Ban-Hock Khor:** Writing – original draft, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Ban-Hock Khor reports a relationship with Malaysian Palm Oil Council that includes: speaking and lecture fees. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] World Health Organization (WHO), Malnutrition [Internet], 2023 [cited 2023 Dec 15] Available from: https://www.who.int/news-room/fact-sheets/detail/malnutrition.

[2] United Nations Children's Fund (UNICEF), World Health Organization, International Bank for Reconstruction and Development/The World Bank, Levels and Trends in Child Malnutrition: Key Findings of the 2021 Edition of the Joint Child Malnutrition Estimates [Internet], World Health Organization, Geneva, 2021 [cited 2023 Dec 15]. 32 pp. https://www.who.int/publications/i/item/9789240025257.

[3] T.Y. Bogale, E.T. Bala, M. Tadesse, B.O. Asamoah, Prevalence and associated factors for stunting among 6–12 years old school age children from rural community of Humbo district, Southern Ethiopia, BMC Publ. Health 18 (1) (2018 May 24) 653, https://doi.org/10.1186/s12889-018-5561-z [Internet].

[4] K. Dereń, S.L. Nyankovskyy, O.S. Nyankovska, E. Łuszczki, J. Wyszyńska, M. Sobolewski, et al., The prevalence of underweight, overweight and obesity in children and adolescents from Ukraine, Sci. Rep. 8 (1) (2018 Feb 26) 3625, https://doi.org/10.1038/s41598-018-21773-4 [Internet].

[5] H. Jebeile, A.S. Kelly, G. O'Malley, L.A. Baur, Obesity in children and adolescents: epidemiology, causes, assessment, and management, Lancet Diabetes Endocrinol. 10 (5) (2022 May 1) 351–365, https://doi.org/10.1016/s2213-8587(22)00047-x [Internet].

[6] Institute for Public Health (IPH), National Health and Morbidity Survey (NHMS) 2019: Vol. I: NCDs – Non Communicable Diseases: Risk Factors and Other Health Problems. Putrajaya, Ministry of Health Malaysia, 2019, p. 386. Available from: https://iku.moh.gov.my/images/IKU/Document/REPORT/NHMS2019/Report_NHMS2019-NCD_v2.pdf.

[7] T. Wu, P.H. Chen, Health consequences of nutrition in childhood and early infancy, Pediatrics Neonatol. 50 (4) (2009 Aug 1) 135–142, https://doi.org/10.1016/s1875-9572(09)60051-6 [Internet].

[8] I. Sioen, L. Van Lieshout, A. Eilander, M. Fleith, S. Lohner, A. Szommer, et al., Systematic Review on N-3 and N-6 polyunsaturated fatty acid intake in European countries in light of the current recommendations - focus on specific population groups, Ann. Nutr. Metabol. 70 (1) (2017 Jan 1) 39–50, https://doi.org/10.1159/000456723 [Internet].

[9] P.C. Calder, Functional roles of fatty acids and their effects on human health, J. Parenter. Enteral Nutr. 39 (1S) (2015 Jul 15), https://doi.org/10.1177/0148607115595980 [Internet].

[10] N. Parletta, P.J. Cooper, D. Gent, J. Petkov, K. O'Dea, Effects of fish oil supplementation on learning and behaviour of children from Australian Indigenous remote community schools: a randomised controlled trial, Prostagl. Leukot. Essent. Fat. Acids 89 (2–3) (2013 Aug 1) 71–79, https://doi.org/10.1016/j.plefa.2013.05.001 [Internet].

[11] V.P. Reyes, M. Pérez-GarcíA, Y. Loya-Méndez, A.E. Puente, Clinical significance of neuropsychological improvement after supplementation with omega-3 in 8–12 years old malnourished Mexican children: a randomized, double-blind, placebo and treatment clinical trial, Res. Dev. Disabil. 35 (4) (2014 Apr 1) 861–870, https://doi.org/10.1016/j.ridd.2014.01.013 [Internet].

[12] L.T. Morenga, J.M. Montez, Health effects of saturated and trans-fatty acid intake in children and adolescents: systematic review and meta-analysis, PLoS One 12 (11) (2017 Nov 17) e0186672, https://doi.org/10.1371/journal.pone.0186672. Internet].

[13] H. Niinikoski, A. Jula, J. Viikari, T. Rönnemaa, P. Heino, H. Lagström, et al., Blood pressure is lower in children and adolescents with a Low-Saturated-Fat diet since infancy, Hypertension 53 (6) (2009 Jun 1) 918–924, https://doi.org/10.1161/hypertensionaha.109.130146 [Internet].

[14] F. Riordan, R. McGann, C. Kingston, I.J. Perry, M.B. Schulze, L.F. Andersen, et al., A systematic review of methods to assess intake of saturated fat (SF) among healthy European adults and children: a DEDIPAC (Determinants of Diet and Physical Activity) study, BMC Nutrition 4 (1) (2018 May 8) 21, https://doi.org/10.1186/s40795-018-0231-1 [Internet].

[15] A. Baylin, H. Campos, The use of fatty acid biomarkers to reflect dietary intake, Curr. Opin. Lipidol. 17 (1) (2006 Feb 1) 22–27, https://doi.org/10.1097/01.mol.0000199814.46720.83 [Internet].

[16] C.R. Monnard, M. Fleith, Total fat and fatty acid intake among 1–7-year-old children from 33 countries: comparison with international recommendations, Nutrients 13 (10) (2021 Oct 9) 3547, https://doi.org/10.3390/nu13103547 [Internet].

[17] D. Parasannanavar, I. Gaddam, T. Bukya, A.I. S, S.R. K, S.K. Banjara, et al., Omega-3 polyunsaturated fatty acid intake and plasma fatty acids of school going Indian children - a cross-sectional study, Prostagl. Leukot. Essent. Fat. Acids 170 (2021 Jul 1) 102294, https://doi.org/10.1016/j.plefa.2021.102294 [Internet].

[18] E.C.H. Tan, R. Avoi, F. Robinson, M.S. Jeffree, S.S.S.A. Rahim, M.Y. Ibrahim, et al., The association of eating behaviour on the growth of children from the interior districts of Sabah, Malaysia, Risk Manag. Healthc. Pol. 15 (2022 Apr 1) 563–570, https://doi.org/10.2147/rmhp.s330358 [Internet].

[19] L. Naing, T. Winn, B.N. Rusli, Practical issues in calculating the sample size for prevalence studies, Arch. Orofac. Sci. 1 (2006) 9–14.

[20] Department of Statistics, Household income and expenditure [Cited 2023 Dec 15]. Available from: https://open.dosm.gov.my/dashboard/household-income-expenditure, 2023.

[21] E.S. Tee, M.N. Ismail, A. Mohd Nasir, I. Khatijah, Nutrient Composition of Malaysian Foods, fourth ed., Institute for Medical Research, Kuala Lumpur, 1997.

[22] Health Promotion Board, Energy and nutrient composition of foods [Internet]. [Cited 2023 Sept 18]. Available from: https://focos.hpb.gov.sg/eservices/ENCF/.

[23] A.E. Black, Critical evaluation of energy intake using the Goldberg cut-off for energy intake:basal metabolic rate. A practical guide to its calculation, use and limitations, Int. J. Obes. 24 (9) (2000 Aug 24) 1119–1130, https://doi.org/10.1038/sj.ijo.0801376 [Internet].

[24] W.N. Schofield, Predicting basal metabolic rate, new standards and review of previous work, Hum. Nutr. Clin. Nutr. 39 (S1) (1985) 5–41.

[25] B.K. Poh, M.N. Ismail, H. Zawiah, C.J.K. Henry, Predictive equations for the estimation of basal metabolic rate in Malaysian adolescents, Malaysia J. Nutrition 5 (1999 Dec) 1–14.

[26] S. Lioret, M. Touvier, M. Balin, I. Huybrechts, C. Dubuisson, A. Dufour, et al., Characteristics of energy under-reporting in children and adolescents, Br. J. Nutr. 105 (11) (2011 Jan 25) 1671–1680, https://doi.org/10.1017/s0007114510005465 [Internet].

[27] Z.W. Yeak, K.A. Chuah, C.H. Tan, M. Ezhumalai, K. Chinna, K. Sundram, et al., Providing comprehensive dietary fatty acid profiling from saturates to polyunsaturates with the Malaysia lipid study-food frequency questionnaire: validation using the triads approach, Nutrients 13 (1) (2020 Dec 31) 120, https://doi.org/10.3390/nu13010120 [Internet].

[28] National Coordinating Committee on Food and Nutrition, Recommended Nutrient Intake (RNI) for Malaysia. Putrajaya, Ministry of Health, 2017.

[29] European Food Safety Authority, Scientific Opinion on Dietary Reference Values for fats, including saturated fatty acids, polyunsaturated fatty acids, monounsaturated fatty acids, trans fatty acids, and cholesterol, EFSA J. 8 (3) (2010 Mar 1) 1461, https://doi.org/10.2903/j.efsa.2010.1461 [Internet].

[30] B.K. Poh, J.E. Wong, S.T. Lee, J.S.M. Chia, G.S. Yeo, R. Sharif, et al., Triple burden of malnutrition among Malaysian children aged 6 months to 12 years: current findings from SEANUTS II Malaysia, Publ. Health Nutr. (2023 Nov 7) 1–36, https://doi.org/10.1017/s1368980023002239 [Internet].

[31] Mulyaningsih Widyaningsih, R. Rahmawati, D. Adhitya, Determinants of socioeconomic and rural-urban disparities in stunting: evidence from Indonesia, Rural Rem. Health 22 (1) (2022 Mar 21) 7082, https://doi.org/10.22605/rrh7082 [Internet].

[32] S. Wu, Y. Ding, F. Wu, R. Li, Y. Hu, J. Hou, et al., Socio-economic position as an intervention against overweight and obesity in children: a systematic review and meta-analysis, Sci. Rep. 5 (1) (2015 Jun 26) 11354, https://doi.org/10.1038/srep11354 [Internet].

[33] N. Akseer, H. Tasic, M.N. Onah, J. Wigle, R. Rajakumar, D. Sánchez-Hernández, et al., Economic costs of childhood stunting to the private sector in low- and middle-income countries, EClinicalMed. 45 (2022 Mar 1) 101320, https://doi.org/10.1016/j.eclinm.2022.101320 [Internet].

[34] J. Ling, S. Chen, N.R. Zahry, T.A. Kao, Economic burden of childhood overweight and obesity: a systematic review and meta-analysis, Obes. Rev. 24 (2) (2022 Nov 27), https://doi.org/10.1111/obr.13535 [Internet].

[35] Z.M. Shariff, K.G. Lin, S. Sariman, H.S. Lee, Y.S. Chin, B.N.M. Yusof, et al., The relationship between household income and dietary intakes of 1-10 year old urban Malaysian, Nutr. Res. Prac. 9 (3) (2015 Jan 1) 278–287, https://doi.org/10.4162/nrp.2015.9.3.278 [Internet].

[36] World Health Organization, Saturated Fatty Acid and Trans-fatty Acid Intake for Adults and Children: WHO Guideline, World Health Organization, Geneva, 2023.

[37] T. Karupaiah, K.A. Chuah, K. Chinna, P. Pressman, R. Clemens, A.W. Hayes, et al., A Cross-Sectional Study on the dietary pattern impact on cardiovascular disease biomarkers in Malaysia, Sci. Rep. 9 (1) (2019 Sep 20), https://doi.org/10.1038/s41598-019-49911-6 [Internet].

[38] National Coordinating Committee on Food and Nutrition, Malaysian Dietary Guidelines 2020. Putrajaya, Ministry of Health, 2020.

[39] L. Gramlich, C. Ireton-Jones, J.M. Miles, M.M. Morrison, A. Pontes-Arruda, Essential fatty acid requirements and intravenous lipid emulsions, J. Parenter. Enteral Nutr. 43 (6) (2019 Mar 25) 697–707, https://doi.org/10.1002/jpen.1537 [Internet].

[40] N.A. Muhamad, J. Mohamad, Fatty acids composition of selected Malaysian fishes, Sains Malays. 41 (1) (2012) 81–94. Available from: http://www.ukm.edu.my/jsm/pdf_files/SM-PDF-41-1-2012/10%20Nur%20Airina.pdf.

[41] B. Burns-Whitmore, E. Froyen, C. Heskey, T. Parker, G.S. Pablo, Alpha-Linolenic and linoleic fatty acids in the vegan diet: do they require Dietary Reference Intake/Adequate Intake special consideration? Nutrients 11 (10) (2019 Oct 4) 2365, https://doi.org/10.3390/nu11102365 [Internet].

[42] Y. Moradi, J. Bakar, A.A. Motalebi, S.N. Muhamad, Y.C. Man, A review on fish lipid: composition and changes during cooking methods, J. Aquat. Food Prod. Technol. 20 (4) (2011 Oct 1) 379–390, https://doi.org/10.1080/10498850.2011.576449 [Internet].

[43] A.M. Cisneros-Montemayor, D. Pauly, L.V. Weatherdon, Y. Ota, A global estimate of seafood consumption by coastal Indigenous peoples, PLoS One 11 (12) (2016 Dec 5) e0166681, https://doi.org/10.1371/journal.pone.0166681 [Internet].