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Vitamin D deficiency in Malaysian adolescents aged 13 years: findings from the Malaysian Health and Adolescents Longitudinal Research Team study (MyHeARTs)

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ABSTRACT

Objective: To determine the prevalence of vitamin D deficiency (<37.5 nmol/L) among young adolescents in Malaysia and its association with demographic characteristics, anthropometric measures and physical activity.

Design: This is a cross-sectional study among Form 1 (year 7) students from 15 schools selected using a stratified random sampling design. Information regarding sociodemographic characteristics, clinical data and environmental factors was collected and blood samples were taken for total vitamin D. Descriptive and multivariable logistic regression was performed on the data.

Setting: National secondary schools in Peninsular Malaysia.

Participants: 1361 students (mean age 12.9±0.3 years) (61.4% girls) completed the consent forms and participated in this study. Students with a chronic health condition and/or who could not understand the questionnaires due to lack of literacy were excluded.

Main outcome measures: Vitamin D status was determined through measurement of sera 25-hydroxyvitamin D (25(OH)D). Body mass index (BMI) was classified according to International Obesity Task Force (IOTF) criteria. Self-reported physical activity levels were assessed using the validated Malay version of the Physical Activity Questionnaire for Older Children (PAQ-C).

Results: Deficiency in vitamin D was seen in 78.9% of the participants. The deficiency was significantly higher in girls (92.6%, p<0.001), Indian adolescents (88.6%, p<0.001) and urban-living adolescents (88.8%, p<0.001). Females (OR=8.98; 95% CI 6.48 to 12.45), adolescents with wider waist circumference (OR=2.64; 95% CI 1.65 to 4.25) and in urban areas had higher risks (OR=3.57; 95% CI 2.54 to 5.02) of being vitamin D deficient.

Conclusions: The study shows a high prevalence of vitamin D deficiency among young adolescents. Main risk factors are gender, ethnicity, place of residence and obesity.

Strengths and limitations of this study

- First study among a cohort of adolescents in Malaysia.
- Data from different waves of this longitudinal study will provide richer evidence on exposure to risk for vitamin D deficiency among adolescents.
- A major limitation of this report is that there are many other risk factors to vitamin D deficiency such as skin pigmentation, cloud cover, amount of clothing and nutritional intake not reported here, but we have taken further steps in the next wave to resolve those issues.

INTRODUCTION

Vitamin D (calciferol) is a group of fat-soluble secosteroid hormones important in calcium and bone metabolism. Lack of vitamin D manifests as rickets in children and degenerative bone diseases in older people.[1] Other studies have additionally shown a relationship between vitamin D deficiency and increased risks of developing chronic illnesses, such as type 1 diabetes and cancer[2] as well as cardiovascular diseases[3] in adults. Chowdhury *et al*[4] in their meta-analysis revealed a potentially deleterious role of low vitamin D in all-cause and cause-specific mortality in primary and secondary prevention cohorts. This finding is of significant public health importance, as the gradual decline in circulating 25-hydroxyvitamin D (25(OH)D) concentrations reported globally is likely to continue owing to the increase in the proportion of older populations, obesity and lack of adequate sun exposure combined with sunscreen use. The effects of vitamin D inadequacy in adolescents have not been investigated as thoroughly, although it is suspected to be associated with early-onset osteomalacia and hypocalcemia in the case where deficiency is extreme.[5]

Adolescence is a period where rapid skeletal growth equates to rapid vitamin D usage. The Ministry of Health Malaysia has suggested a cut-off point of 200 IU per day (5 µg) of vitamin D intake for males and females aged between 13 and 18 years.[6] Dermal synthesis is the major natural source of vitamin D (90%) as very few foods naturally contain vitamin D. Provided that there is sufficient skin exposure to sunlight, enough is synthesised from its precursor molecule 7-dehydrocholesterol to achieve the required daily intake level.[7] Other factors such as diet, skin colour and clothing also influence the serum concentration of vitamin D in a person.[7–9]

The prevalence of severe vitamin D deficiency in adolescents is variable, but it is considerably high in many countries, especially in the Middle East and Southeast Asia.[2 7] Comparatively, Malaysia has reported a better vitamin D status than other countries[2] due to its location near the equator. Despite this, studies involving selected groups have indicated the presence of vitamin D deficiency within the population.[8] This is an unexpected outcome given that Malaysia is a tropical country receiving an average of 7–8 hours of intense sunlight daily; far surpassing the 6–8 min needed for adequate vitamin D production to occur.[10] Nonetheless, it is not an isolated finding. A similar pattern of deficiency has been shown among adults, children and infants in India,[11] which is also a country with abundant sunlight throughout the year.

There has been a significant rise in the incidence of non-communicable diseases (NCDs) in Malaysia in recent years. Malaysia has the highest number of overweight, obese as well as diabetic adults compared with other countries in the region, and the trend is increasingly seen among its adolescents as well.[12] It is imperative for the future of the country that all risk factors, especially modifiable risk factors such as the lack of vitamin D, be investigated and acted upon. The current lack of data on vitamin D deficiency among adolescents in Malaysia prompted this study, which aims to report on the prevalence of vitamin D deficiency among Malaysian adolescents and its association with certain demographic and risk factors. Such information may aid in developing preventive and intervention strategies to improve vitamin D status in adolescents and prevent the development of NCDs in adult life.

Methods

The data were drawn from the first wave of the Malaysian Health and Adolescents Longitudinal Research Team study (MyHeARTs) project, an ongoing prospective cohort study which plans to follow the adolescents until they reach adulthood. The first wave was conducted from March to May 2012, and involved students from 15 randomly selected public secondary schools in central and northern Malaysia (the states of Perak, Selangor and the Federal Territory of Kuala Lumpur). The study protocol has been published in detail elsewhere.[13]

Study population

The study population comprised Form 1 (aged 12–13 years) students, that is, in their first year of secondary school (Form 1 is equivalent to year 7 in the British education system). Students in boarding, religious or vernacular schools were excluded as they are not representative of Malaysian public schools, which the majority of students attend. Only students and their parents/guardians who had submitted completed consent forms were recruited into the study.

Study design

The MyHeARTs study used a multistage stratified sampling design. The first stage involved selecting two out of four educational regions of Peninsular Malaysia based on probability proportionate to the population size. The second stage involved the selection of schools. A complete list of public secondary schools located in the selected region was obtained from the Ministry of Education Malaysia and used as the sampling frame. The schools were classified as urban and rural based on criteria provided by the Department of Statistics Malaysia. Schools from the urban and rural locations were randomly selected using computer-generated random number lists. In total, there were 595 public schools (238 in Perak (northern region) and 315 in Selangor and Wilayah Persekutuan Kuala Lumpur (WPKL) (central region)). Out of the 15 schools randomly selected, 7 were in Perak, 5 in Selangor and 3 in WPKL. In the final stage, all eligible students from the selected schools were invited to participate in the study. Consent forms, together with a detailed information sheet, were distributed through the school authorities.

The exclusion criteria were students with any type of chronic health condition and those who were not able to answer the questionnaires in either English or Malay. Exclusion was made as well for chronic diseases that could affect growth or the metabolism of calcium or vitamin D (such as calcium metabolism disorders) and malnutrition (defined as a weight/height ratio<−2 SD).

Sample size

Using the formula $n=(z^2pq/re^2)\times$ design effect, and taking the prevalence of smoking among school-based adolescents aged 13–15 years in Malaysia as 33%,[11] the total sample size calculated for this study was 1500. There were 3177 students from the 15 selected schools, 2694 (85%) of whom were eligible for the study and who received consent forms. Out of 2694 students, 1361 participated in the study giving an overall participation rate of 51%. This response rate varied by place of residence (66% in rural schools compared with 42% in urban schools) and by states (42% in Selangor, 50% in WPKL and 61% in Perak).

Blood analysis

Venous blood samples were taken after an overnight fast of at least 10 hours prior to the study visit. Blood samples were collected by a trained phlebotomist and temporarily stored at 4°C in a cool box. The samples were sent to a local pathology laboratory that was International Organization for Standardization (ISO) certified for analysis. Approximately 5 ml of the blood collected was analysed for sera vitamin D. Vitamin D status was determined through measurement of 25(OH)D via electrochemiluminescence immunoassay (ECLIA by Advia Centaur XP) on a Cobas E 411 analyzer. The interassay coefficient of variation (CV) was 3.6% at 57.0 nmol/L (22.8 ng/mL) and 3.0% at 170.5 nmol/L (68.2 ng/mL). The intra-assay CV was 3.5% at 57.0 nmol/L (22.8 ng/mL) and 2.9% at 170.5 nmol/L (68.2 ng/mL). The measuring range for this kit was 10–250 nmol/L or 4–100 ng/mL. During the analytical run of vitamin D, two concentrations of controls were run together with the samples to ensure that the results were reliable.

25(OH)D concentrations were classified based on the cut-off points suggested,[5] <12.5 nmol/L=severely vitamin D deficient; <37.5 nmol/L=vitamin D deficient; between 37.5 and 50 nmol/L=vitamin D insufficient; ≥50 nmol/L=sufficient vitamin D.

Anthropometric measurement

Height was measured without socks and shoes using a calibrated vertical Seca 217 portable stadiometer (Seca, UK) to the nearest millimetre. Weight was measured with light clothing using a Seca 813 (Seca, UK) digital electronic weighing scale, to the nearest decimal fraction of a kilogram. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in metres. The BMI z-score for age and gender was calculated using the WHO Anthro Software V.3.2.2 for the Statistical Package for the Social Sciences (SPSS) macro, based on WHO reference 2007 (WHO, Geneva, Switzerland). Body fat percentage was measured using a portable body composition analyzer (Tanita SC 240 MA Portable Body Composition Analyser, Tanita Europe B.V., The Netherlands). Waist circumference (WC) was measured with a non-elastic measuring tape (Seca 201, Seca, UK) that was positioned midway between the lowest rib margin and the iliac crest. Measurement was calculated to the nearest millimetre.

The participants were classified into four categories (obese, overweight, normal and underweight) as established by International Obesity Task Force (IOTF) in the year 2000, based on pooled international data for BMI linked to the adults cut-off values. Central obesity was defined by waist circumference ≥90th centile as determined by waist circumference centile curves for Malaysian children and adolescents.[14] The cut-off value used was 83.8 cm for males and 78.8 cm for females.

Assessment of physical activity

Self-reported physical activity levels were assessed using the validated Malay version of the Physical Activity Questionnaire for Older Children (PAQ-C), which has reported satisfactory internal consistency and acceptable validity.[15 16] Ten items in the PAQ-C were designed to capture the level of physical activity over the course of the 7 days prior to filling in the questionnaire. The mean self-reported physical activity score was further categorised into low (score <2.33), moderate (2.33–3.66) and high (score >3.66) levels.[15 16]

Demographic characteristics

The sociodemographic information such as gender, age, ethnic group, the educational status and occupational status of the parents was collected from the self-administered questionnaires.

Ethical approval

Participation in the study was voluntary and written informed consent for participation in the study was obtained from the students as well as their parents/guardians.

Statistical analysis

All data including sociodemographic data, anthropometric measurements and biochemical measurements were analysed using SPSS Statistics for Windows, V.22.0. (IBM Corp, Armonk, New York, USA). Categorical variables (gender, ethnicity, place of residence, body fatness) were described as frequencies and percentages. The associations between categorical data were measured using χ^2 statistics. The association between outcome (mean vitamin D) and determinants was assessed using Student's t-test and analysis of variance (ANOVA). For significant results in ANOVA, post hoc tests (Tukey) were performed. Measure of effect (OR) and 95% CI between potential risk factors and outcome, vitamin D deficiency, were analysed by performing univariable and multivariable logistic regression. All results were interpreted using p<0.05 (two sided) as the criterion for statistical significance.

RESULTS

A total of 1361 Form 1 students (mean age: 12.9 ±0.3 years; 61.4% females) participated in this study. The sociodemographic characteristics of the participants are presented in table 1. The majority of the participants were of Malay ethnicity, 80.2% (n=1091), followed by Chinese 7.7% (n=105), Indians 7.7% (n=105) and other ethnic groups 3.0% (n=41). Students from urban (53.9%, n=723) and rural locations (46.9%, n=638) were equally represented. The prevalence of overweight and obesity in this population was 23.9% (n=326), whereby 15.4% (n=210) were overweight and 8.5% (n=116) were obese. Another 21.0% (n=286) was underweight. A total of 63% (n=858) of the adolescents were classified as having low physical activity, with the remaining 37% had moderate to high levels of physical activity.

Table 1 Sociodemographic characteristics, physical activities and vitamin D levels of the adolescents

Characteristics/variables	Total adolescents n (%)	Male n (%)	Female n (%)
Ethnicity			
Malay	1091 (80.2)	420 (80.0)	671 (80.3)
Chinese	105 (7.7)	42 (8.0)	63 (7.5)
Indians	105 (7.7)	34 (6.5)	71 (8.5)
Others	41 (3.0)	17 (3.2)	24 (2.9)
Place of residence			
Urban	723 (53.1)	240 (45.7)	483 (57.8)
Rural	638 (46.9)	285 (54.3)	353 (42.2)
BMI			
Underweight	286 (21.0)	103 (19.6)	183 (21.9)
Normal	738 (54.2)	282 (53.7)	456 (54.5)
Overweight	210 (15.4)	82 (15.6)	128 (15.3)
Obese	116 (8.5)	56 (10.7)	60 (7.2)
Physical activity			
Active	858 (63.0)	232 (44.2)	626 (74.9)
Inactive	482 (35.4)	280 (53.3)	202 (24.2)
Vitamin D levels (n=1361)			
Severe deficiency 25(OH)D<12.5 nmol/L	20 (1.5)	2 (0.4)	18 (2.2)
Deficiency 12.15≤25(OH)D <37.5 nmol/L	1053 (77.4)	297 (56.6)	756 (90.4)
Insufficiency 37.5≤25(OH)D ≤50 nmol/L	187 (13.7)	135 (25.7)	52 (6.2)
Sufficient 25(OH)D>50 nmol/L)	101 (7.4)	91 (17.3)	10 (1.2)

25(OH)D, 25-hydroxyvitamin D; BMI, body mass index.

The prevalence of vitamin D deficiency (serum 25(OH)D level, ≤37.5 nmol/L) in the total sample was 78.9% (n=1073) with 1.5% (n=20) severely vitamin D deficient (25(OH)D level, ≤12.5 nmol/L). Vitamin D insufficiency (25(OH)D level, between 37.5 and 50 nmol/L) was seen in 187 participants (13.7%). Only 101 of the participants (7.4%) had a sufficient vitamin D level >50 nmol/L.

There was a statistically significant difference between gender, ethnicity, place of residence, BMI, waist circumference, levels of physical activity and mean vitamin D as determined by one-way ANOVA (7.677(3.101), p<0.001) (table 2). A Tukey post hoc test revealed the mean vitamin D level among males (37.4±1.2 nmol/L) was significantly higher compared with females (24.2 ±0.6 nmol/L). The tests also revealed that the mean vitamin D level among Chinese (30.8±1.8 nmol/L) was significantly higher compared with Malays (29.1 ±0.8 nmol/L) and Indians (26.6±1.6 nmol/L). Although the mean vitamin D level of the 'other' group of ethnicities was highest at 36.1 (±5.0 nmol/L); the result was not tested as the numbers in this group were small (n=41).

The mean serum 25(OH)D level was lower among adolescents living in urban areas (25.3 nmol/L) compared with those residing in a more rural setting (33.7 nmol/L). All three anthropometric measures (BMI, waist circumference and body fat percentages) showed that those who are obese have a lower mean serum 25(OH)D level compared with those who were normal in weight and other measures. There were also significant differences in mean serum 25(OH)D level between adolescents who are physically inactive (27.6 nmol/L) compared with those who are active (32.2 nmol/L). Among the parental characteristics, variables such as education and employment of either father or mother did not produce significant differences in vitamin D concentrations.

Following multivariable analysis, the results (table 3) showed that gender, waist circumference and place of residence had a significant relationship to vitamin D deficiency. Females were more at risk than males (OR=8.98; 95% CI 6.5 to 12.4), adolescents in urban areas are more at risk (OR=3.5; 95% CI 2.5 to 5.0) than adolescents in rural areas and adolescents with wider waist circumference were more at risk (OR=2.64; 95% CI 1.65 to 4.25) than those with normal waist circumference.

DISCUSSION

This study was conducted on adolescents aged 13 years from rural and urban areas in Malaysia. The majority of the students were of Malay ethnicity, followed by Chinese and Indian. As there were more Malays in this study, the results may not be generalised to the whole population of Malaysia and the urban areas in particular, but they are representative of the Malay and Indian population as well as the population in rural areas.

The study revealed that the prevalence of vitamin D deficiency among Malaysian adolescents of this age group is high at 78.8%. This shows that 8 out of 10 healthy asymptomatic adolescents in Malaysia are suffering from vitamin D deficiency. A similar study conducted in 2008 among

Table 2 The vitamin D levels of the adolescents with severe vitamin D deficiency, vitamin D deficiency, insufficiency and sufficiency by demographic characteristics and anthropometric measures

Variables	Severe deficiency n (%)	Deficiency n (%)	Insufficiency n (%)	Sufficiency n (%)	Mean vitamin D (nmol/L)	*p Value
Gender						
Male	2 (0.4)	297 (56.6)	135 (25.7)	91 (17.3)	37.4±1.2	<0.001
Female	18 (2.2)	756 (90.4)	52 (6.2)	10 (1.2)	24.2±0.6	
Ethnicity*						
Malay	17 (1.6)	840 (77.0)	144 (13.2)	90 (8.2)	29.1±0.8	0.001
Chinese	1 (1.0)	89 (84.8)	13 (12.4)	2 (1.0)	30.8±1.8	
Indian	2 (1.9)	91 (86.7)	10 (9.5)	2 (1.9)	26.6±1.6	
Others	0 (0)	25 (61.0)	9 (22.0)	7 (17.1)	36.1±5.0	
Place of residence						
Urban	18 (2.5)	624 (86.3)	71 (9.8)	10 (1.4)	25.3±0.7	<0.001
Rural	2 (0.3)	429 (67.2)	116 (18.2)	91 (14.3)	33.7±1.1	
BMI*						
Underweight	3 (1.0)	217 (75.9)	38 (13.3)	28 (9.8)	30.5±1.5	0.006
Normal	10 (1.4)	550 (74.5)	120 (16.3)	58 (7.9)	29.8±0.9	
Overweight	2 (1.0)	179 (85.2)	22 (10.5)	7 (3.3)	27.3±1.4	
Obese	4 (3.4)	98 (84.5)	7 (6.0)	7 (6.0)	26.8±2.2	
Body fat (%)						
Normal	13 (1.45)	667 (74.20)	138 (15.35)	81 (9.01)	28.6±12.5	0.609
High	6 (1.33)	376 (83.56)	49 (10.89)	19 (4.22)	26.2±10.9	
Waist circumference (cm)						
Normal	15 (1.33)	850 (74.20)	167 (14.84)	93 (8.27)	29.8±13.0	0.001
High	4 (1.78)	194 (86.22)	20 (8.89)	7 (3.11)	26.9±10.4	
Physical activity						
Inactive	14 (1.6)	704 (82.1)	97 (11.3)	43 (5.0)	27.6±0.8	<0.001
Active	6 (1.2)	340 (70.5)	79 (16.4)	57 (11.8)	32.2±1.3	
Father						
Education						
Form 3 and below	5 (1.2)	328 (77.0)	55 (12.9)	38 (8.9)	29.7±1.3	NS
Form 4 and above	15 (2.2)	534 (78.2)	95 (13.9)	39 (5.7)	28.5±0.9	
Employment						
Working full time	15 (1.8)	667 (78.4)	114 (13.4)	55 (6.5)	28.6±0.9	NS
Not working full time	5 (2.3)	165 (75.0)	35 (15.9)	15 (6.8)	29.4±1.6	
Mother						
Education						
Form 3 and below	6 (1.4)	345 (80.2)	46 (10.7)	33 (7.7)	29.3±1.2	NS
Form 4 and above	14 (1.9)	559 (76.9)	109 (15.0)	45 (6.2)	28.6±0.9	
Employment						
Working full time/part-time	8 (1.2)	541 (78.7)	91 (13.2)	47 (6.8)	29.0±1.0	NS
Housewives/not working	12 (2.6)	357 (76.8)	65 (14.0)	31 (6.7)	28.7±1.1	

Means are presented with SDs.
*p Values were obtained from ANOVA with Tukey's multiple post hoc testing. p Values are used to compare means. Cut-off points: body fat (normal: boy <22%, girl <29%; high: boy ≥22%, girl ≥29%), waist circumference (cm) (normal: boy <83.8, girl <78.8; high: boy ≥83.8, girl ≥83.8).
ANOVA, analysis of variance; BMI, body mass index; NS, not significant.

primary school children (aged 7–12 years) also showed a high prevalence of vitamin D deficiency (<50 nmol/L) at 35.3%.[8] Another nationally representative study among younger children (aged 8–12 years) in 2013 also revealed that almost half the children (47·5%) had vitamin D insufficiency.[17] Interestingly, studies involving the older population of Malaysia also revealed similar results. In a study among postmenopausal women aged 50–65 years in 2004, the prevalence of vitamin D deficiency (<50 mmol/L) among Malay women was 73.3% and 12.2% was among Chinese women.[18] Moy and Bulgiba[19] found the prevalence of vitamin D deficiency (<50 nmol/L) among a convenience sample of Malay employees (mean age around 48.5 years (SD 5.2 years)) in one public university to be 87% in females and 41% in males. Green *et al*[7] found similar findings among a convenience sample of women of childbearing age.

Vitamin D deficiency (inclusive of those with either deficient or severely deficient sera 25(OH)D levels) has been reported among adolescents in several countries including India,[11] China,[20 21] Italy,[22] Norway[23] and other European nations.[24] Comparatively, the prevalence of vitamin D

Table 3 Univariable and multivariable logistic regression between vitamin D deficiency and selected variables

Variables	Total N	Vitamin D deficiency 25(OH)D ≤37.5 n (%)	Unadjusted OR (95% CI)	Adjusted OR (95% CI), adjusted for multiple variables
All	1361	1073 (78.8)	NA	NA
Gender				
Male	525	299 (57.0)	Ref	Ref
Female	836	774 (92.6)	8.62 (6.33 to 11.75)*	8.98 (6.48 to 12.45)*
Ethnicity‡				
Malay	1091	857 (78.6)	0.65 (0.38 to 1.14)	1.24 (0.65 to 2.36)
Chinese	105	90 (85.7)	Ref	Ref
Indian	105	93 (88.6)	1.39 (0.62 to 3.11)	1.43 (0.59 to 3.48)
Others	41	25 (61.0)	0.28 (0.12 to 0.64)†	0.50 (0.19 to 1.32)
Place of residence				
Rural	638	431 (67.6)	Ref	Ref
Urban	723	642 (88.8)	3.70 (2.79 to 4.91)*	3.57 (2.54 to 5.02) *
Waist circumference (cm)‡				
Normal	1125	850 (75.5)	Ref	Ref
High	225	194 (86.2)	2.23 (1.45 to 3.44)*	2.64 (1.65 to 4.25)*
Physical activity‡				
Inactive	858	718 (67.5)	1.95 (1.49 to 2.55)*	0.97 (0.69 to 1.34)
Active	482	346 (32.5)	Ref	Ref

Vitamin D deficiency is defined as those severely deficient (<12.5 nmol/L) and those deficient (12.5–37.5 nmol/L) in 25 OHD.
*Indicates p<0.001.
†Indicates p<0.05 for statistical significance.
‡Indicates missing values from the total of 1361 participants. OR was obtained from simple unadjusted logistic regression. Adjusted OR was obtained using multivariable logistic regressions adjusted for gender, ethnicity, place of residence, waist circumference and physical activity.
25(OH)D, 25-hydroxyvitamin D; NA, not applicable; Ref, reference.

deficiency as shown by 78.9% of the adolescents in our study population is much higher than the vitamin D deficiency numbers exhibited by adolescents in China (68.4%),[21] despite the research conducted during winter, and in Italy[22] at 38.7%. There appears to be a paradox here; neither of those countries has as much sunlight exposure as Malaysia, given its geographical location very near to the equator. However, seasonal exposure to sunlight might be a good explanation as to why some countries, as mentioned above, have a better vitamin D level compared with Malaysia. Italy, for example, has a higher exposure to sunlight from May through September,[22] thus contributes to a better vitamin D level. Impact of seasonal exposure to sunlight and its impact on vitamin D synthesis would require further investigation in order for us to come up with good justification. Furthermore, when adolescents with insufficient levels of 25(OH)D at >37.5 to <50 nmol/L were included, the prevalence of hypovitaminosis D among Malaysian adolescents is at an astonishingly high level of 92.6%. This is a worrying trend as it shows how prevalent vitamin D deficiency is in the population, which should warrant immediate attention.

However, severe deficiency was reported in only 1.5% of the adolescents in this study. This is a significantly lower percentage than that reported among Italian adolescents[22] at 6.4%, but similar to the Norwegian data[23] at 1.6%. In Asian populations, a study in Beijing showed 40% of adolescent girls were severely deficient in vitamin D, particularly during the winter season.[20] Trends of seasonal-dependence of vitamin D deficiency were also found in regions neighbouring China, such as Mongolia[25] and Iran.[26]

Similar to others' findings, the prevalence of vitamin D deficiency in our cohort was more severe in girls than boys. It has been shown again and again to be much more prevalent in females of this age range (aged 9–18 years) then it is among boys of the same age range.[11 24] In this study, girls had higher odds (OR=8.98; 95% CI 6.48 to 12.45) of having vitamin D deficiency compared with boys. Habibesadat *et al*[26] reported similar results of vitamin D deficiency among adolescents aged 7–18 years old in North Khorasan, Iran where the age-adjusted odds of serum 25(OH)D <30 nmol/L was 21.12 higher in girls compared with boys. Postulations as to why girls are more susceptible to vitamin D deficiency include the more modest dress codes observed by many girls in this region, as well as the habit of avoiding the sun for cosmetic reasons.

The prevalence of vitamin D deficiency was also shown to be higher among Malaysian adolescents of Indian and Malay ethnicity compared with the Chinese. These findings have been recorded repeatedly in various studies,[7 8 27] indicating that there could be a relationship between greater pigmentation and a less than ideal vitamin D status. Production of vitamin D precursors from exposure to UV radiation is inversely correlated with skin melanin density.[28 29] Consistently, our study also saw the darker skinned adolescents of Indian ethnicity displaying the lowest average sera vitamin D concentrations, when compared with their Malay and Chinese counterparts. However, further investigations, such as measuring sun exposure and level of skin pigmentation, are needed before validating them as tools for predicting vitamin D levels.

Our study found that vitamin D deficiency was greater in obese adolescents. Other Malaysian studies such as Khor *et al*'s[8] and Poh *et al*'s[17] have demonstrated the same findings. A Dutch study among multiethnic children also reported that the prevalence of insufficient vitamin D was higher among obese non-white children compared with normal-weight white children.[30]

Maintaining vitamin D sera 25(OH)D levels above 50 nmol/L could enhance bone health, increase bone density in adolescent girls,[31] and suppress excessive production of parathyroid hormones.[32] A study among Korean adolescents aged 12–19 years showed positive correlations between adequate vitamin D and lowered risks of abdominal obesity, obesity and metabolic syndromes.[33] However, though ≥37.5 nmol/L is generally accepted as a measure of vitamin D sufficiency in adolescents, there may be other confounding variables that could alter the optimal level for this age group; such as an individual's level of physical activity and vitamin D metabolizing capability. Therefore, further studies will be carried out to support these findings by taking such factors into account, in order to establish an optimal vitamin D level for Malaysian adolescents.

As previously mentioned, the production of vitamin D precursors from exposure to UV radiation is inversely correlated with skin melanin density.[28 29] Other than low exposure to sunshine, low vitamin D levels in children and adolescents could be the result of poor dietary intake, as suggested by previous studies.[24 34 35] It is fortunate that this study has not neglected the diet component. All participants reported their food consumption over a 7-day period to trained dietitians in order to capture comprehensive nutrient consumption. Further analysis of the diet of the participants and other nutritional factors such as calcium intake and parathyroid hormone (PTH) levels to depict any clinical implications of vitamin D deficiency will be undertaken in the future.

Our results also showed that there is a relationship between low physical activity and vitamin D deficiency, although it is not significant. Moreover, other studies among adolescents[20 21] have shown that outdoor exercise does indeed increase vitamin D levels in sera. It is thus expected that the more physically active you are, the higher the level of vitamin D in your body.

It is interesting to note that there is a significant association between place of residence and vitamin D deficiency. This study revealed that adolescents in urban areas are more at risk of being deficient in vitamin D (OR=3.57; 95% CI 2.54 to 5.02) compared with adolescents in rural areas. This could be due to lack of exposure to the sun caused by lack of involvement in outdoor activities due to environmental pollution or lack of recreational facilities in urban areas.

Although the occupational and educational status of the parents did not produce any significant differences in vitamin D levels among their children in this study, others have shown that vitamin D levels do differ between the upper and lower working classes. This is most likely due to differences in the quality of the foods that are consumed on a daily basis. As a result, vitamin D deficiency is typically higher among those with lower socioeconomic status (SES). This finding had been described in populations in the USA,[36] Finland[37] and India.[38] One of the limitations of this study is the lack of income data or data that truly measure SES. Thus, classification of the employment and educational level of the parents might not be reflective of the SES of the families. Further studies are needed to determine how SES and other lifestyle factors contribute significantly to vitamin D levels.

The strength of our study is the large sample of participants. To our knowledge, this is the first large cross-sectional study in Malaysia to determine the vitamin D level among school-going adolescents. There are limitations to this study. The cross-sectional design cannot capture the cause–effect relationship. The cohort sample are of the same age group, thus do not reflect the whole adolescent population. More than 80% of the participants were Malays, which does not reflect the racial composition of Malaysian adolescents. However, this study is still of importance since it is one of only a few that have examined vitamin D levels. Our next step will be in MyHeARTs II 2014, where a follow-up of the same participants will be conducted, through which we hope to establish the longitudinal association between lifestyle factors and vitamin D levels.

CONCLUSION

It is somewhat unexpected that despite the country being close to the equator (2°N), the population of adolescents has suboptimal vitamin D status. It is thus imperative to conduct further investigation on why there is such a high prevalence of vitamin D deficiency among otherwise healthy adolescents. With the strong evidence that vitamin D status is important in the prevention of NCDs in the community, there should be more effort and investment put into carrying out more research into this area and finding effective interventions to reduce the burden of preventable diseases. One of the most effective ways to improve vitamin D status is by increasing outdoor activities. School children can be encouraged to be outdoors during the optimal vitamin D exposure period (in Malaysia, it is between 10:00 and 14:00). This is in fact an effective and economical way for vitamin D improvement. Another candidate intervention that we suggest is through food fortification and supplementation. Supplementation has been proven[24] to enhance vitamin D status. As to whether or not food fortification would generate the same data pattern among adolescents would require further and thorough investigation from future research.

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