Original Article

25-hydroxy-vitamin D demography and the risk of vitamin D insufficiency in the South East Asian Nutrition Surveys (SEANUTS)

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The South East Asian Nutrition Surveys (SEANUTS) were conducted in 2010/2011 in Indonesia, Malaysia, Thailand and Vietnam in country representative samples totalling 16,744 children aged 0.5 to 12 years. Information on socio-demographic and behavioural variables was collected using questionnaires and anthropometric variables were measured. In a sub-sample of 2016 children, serum 25-hydroxy-vitamin D (25(OH)D) was determined. Data were analysed using SPSS complex sample with weight factors to report population representative data. Children were categorized as deficient (<25 nmol/L), insufficient (<50 nmol/L), inadequate (<75 nmol/L) or desirable (≥75 nmol/L). In Malaysia and Thailand, urban children had lower 25(OH)D than rural children. In all countries, except Vietnam, boys had higher 25(OH)D levels and older children had lower 25(OH)D. Regional differences after correcting for age, sex and area of residence were seen in all countries. In Thailand and Malaysia, 25(OH)D status was associated with religion. The percentage of children with adequate 25(OH)D (≥75 nmol/L) ranged from as low as 5% (Indonesia) to 20% (Vietnam). Vitamin D insufficiency (<50 nmol/L) was noted in 40 to 50% of children in all countries. Logistic regression showed that girls, urban area, region within the country and religion significantly increased the odds for being vitamin D insufficient. The high prevalence of vitamin D insufficiency in the (sub) tropical SEANUTS countries suggests a need for tailored approach to successfully combat this problem. Promoting active outdoor livestyle with safe sunlight exposure along with food-based strategies to improve vitamin D intake can be feasible options.

Key Words: vitamin D, 25(OH)D, children, SEANUTS, aetiology

INTRODUCTION

Since the discovery of vitamin D and its chemical structure in last century, its role in calcium metabolism and in the prevention of rickets and osteomalacia has been thought of as the main physiological function. Cod liver drops (high in vitamin D) or synthetic vitamin D pills were often taken early last century to prevent rickets, then commonly seen in northern European countries and in the United States. Many countries still have compulsory vitamin D fortification programs (for example for margarines). Since the availability of adequate methods to assess vitamin D status via 25-hydroxy-vitamin D (25(OH)D) levels in blood, research output on vitamin D status has tremendously increased and has shown that effects of an adequate vitamin D status go further than calcium and phosphate metabolism, rickets and osteomalacia. Low vitamin D status is believed to be associated with increased mortality.[1-3] An adequate vitamin D status may be preventive for colorectal cancer whilst a low level has been associated with increased cancer mortality.[4] There is also increasing evidence for an association of vitamin D status with heart disease,[5] hypertension[6,7] and obesity. However, the advisory committee for the Canadian Ministry of Health[8] concluded in a recent report that there is insufficient evidence for action and

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advice.

Vitamin D status is not only dependent on nutritional intake, but also sunlight exposure.[9-11] UV-B light (290-315 nm) converts 7-hydroxy-cholesterol in the skin to vitamin D-3, which is converted in the liver to 25(OH)D_3. Blood concentrations of 25(OH)D can be used as an indicator of vitamin D status. The recommendations for adequate 25(OH)D range from >25 nmol/L to prevent rickets and osteomalacia to >50 nmol/L for optimal calcium metabolism[8] and well-being as set by the World Health Organisation and even up to 75-110 nmol/L as optimal concentration as reported by Bischoff-Ferrari et al.[12]

It is known that the worldwide prevalence of vitamin D insufficiency (<50 nmol/L) is high[2,13-15] and even increasing.[11,16] It is now accepted to be a worldwide health problem. High prevalence are reported even in (sub) tropical countries like Malaysia,[17] Thailand,[18] Vietnam,[19] Iran,[20,21] Saudi Arabia,[22,23] Australia,[24] and in several populations including children, adolescents and adults.[17-26] The SEANUTS population[27] also showed high prevalence of vitamin D insufficiency, varying from about 30% in Vietnam to over 50% in Indonesia. Individual factors such as sun exposure, dress habits and ethnic differences might be aetiological factors affecting 25(OH)D in addition to regional differences within a country. Knowledge and understanding of these factors would facilitate a tailored approach in possible future intervention strategies.

The aim of this paper is to report the prevalence of vitamin D insufficiency and to identify related factors for the childhood populations in the tropical countries Indonesia, Malaysia, Thailand and Vietnam in order to enable adequate preventive action.

METHODS

General information about the set up and methodology of SEANUTS is described in detail elsewhere.[27-31] In short, SEANUTS is a cross-sectional nutritional survey conducted between 2010 and 2011 in four South East Asian countries among 16,744 children aged 0.5 to 12 years old. The sample selection was based on multi-stage cluster or stratified random sampling and consisted of urban and rural children of both sexes. Weight factors based on census information of the relevant statistical government departments were used to obtain country representative outcomes. The study was conducted according to the guidelines laid down in the Declaration of Helsinki. All procedures were approved by the Medical Ethics Committees of the participating research institutions. Written informed consent was obtained from all the parents or carers of children and verbal assent was obtained from each child before data collection. The study is registered in the Netherlands Trial Registry as NTR2462.

The present study sample consists of randomly selected 2016 children (see Table 1) from whom a venous blood sample was collected for the determination of 25(OH)D levels. All children were older than 2 years. Weight was measured in light clothing using calibrated digital scales accurate to 0.1 kg. Height was measured using wall mounted stadiometers accurate to 0.1 cm without shoes. Body mass index (BMI, kg/m^2) was calculated as weight divided by height squared. Body mass index for age (BAZ) and height for age (HAZ) z-scores were calculateed based on WHO growth standards.[32,33]

Venous blood was taken and serum was immediately put on ice and stored at -80^{o}C till chemical analysis in accredited laboratories. 25(OH)D concentrations in Malaysia and Thailand were determined using the chemiluminescence immunoassay (Diasorin Liaison ® total vitamin D assay),[34] in Vietnam using HPLC,[35] Roche, and in Indonesia using immunoactivity detection system.[36] The 25(OH)D tests in Indonesia, Malaysia and Thailand measure total 25(OH)D (25(OH)D_2 and 25(OH)D_3). The test used in Vietnam measures only 25(OH)D_3. Intra assay CV% in the countries ranged from 2.5 to 5% and inter-assay CV% from 4.2 to 9.2%. Due to the differences in methodologies used for 25(OH)D determination, country data were not combined in the statistical analysis.

Structured questionnaires were used to obtain information about socio-economic parameters from parents or caregivers and behaviour aspects that could possibly affect the exposure to sunshine.[27] Questionnaires were identical for the four countries but were adapted to the local

Table 1. Characteristics of the children in the four countries

	Indonesia		Malaysia		Thailand		Vietnam	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Sample size	276		861		495		384	
Population size	32,838,889		4,720,987		8,293,931		14,871,454	
Age (years)	6.6[†]	0.2	8.1	0.2	8.0	0.2	8.8[‡]	0.1
Rural (%)	56		16		67		76	
Boys (%)	58		53		52		51	
Weight (kg)	19.3	0.7	27.7	0.7	26.6	0.6	25.1	0.4
Height (cm)	111	1.4	125	1.2	124	1.0	126	0.6
BMI (kg/m^2)	15.2	0.2	17.0	0.2	16.4	0.2	15.5	0.1
BAZ	-0.57	0.10	0.08	0.08	-0.17	0.08	-0.61	0.08
HAZ	-1.48	0.09	-0.48	0.06	-0.46	0.05	-0.89	0.07
25(OH)D (nmol/L)	52.7[§]	0.9	55.2	1.1	59.6	1.1	56.3	1.7

BMI: body mass index (kg/m^2); BAZ: body mass index for age z-score; HAZ: height for age z-score; 25(OH)D: 25-hydroxyvitamin D.
[†]25(OH)D levels are based on chemiluminescence immunoassay in Malaysia and Thailand, HPLC in Vietnam and immunoactivity detection system in Indonesia.
[†]Significantly younger (p<0.05) than children from Malaysia, Thailand and Vietnam.
[‡]Significantly older (p<0.05) than children from Indonesia, Malaysia and Thailand.
[§]Significant different (p<0.05) from the other countries after correcting for age, sex and area of residence.

situation. Information about average daily sunshine hours per region in each country was obtained from the appropriate meteorological website[37] and referred to the closest nearby location (city). Influence of nutrition is not covered in this paper due to non-availability (or incomplete data) of vitamin D in local food composition tables.

Data were analysed using IBM SPSS Statistics for Windows (IBM cooperation 2011, Armonk NY), version 20.0.0. All presented results are based on weighted data using country specific weight factors[28-31] in the SPSS 'complex sample' procedure. Differences between groups were tested using analysis of (co)variance techniques after correction for possible confounders. Odds ratios (OR) were calculated using logistic regression. Reference category for calculating OR for inadequate 25(OH)D levels in geographical areas was by default the region with the lowest prevalence of vitamin D insufficiency. Values are expressed as mean and standard error (SE). Level of significance was set at $p<0.05$.

RESULTS

General information and anthropometric characteristics of the children is given in Table 1. Total population size was 60,725,261. The Indonesian children were younger and Vietnamese children older as compared to the Malay and Thai children ($p<0.05$). Weight, height, BMI, HAZ and BAZ did not significantly differ from the total SEANUTS population of the same age in the country.

The 25(OH)D levels did not differ between countries except for Indonesia, which had significantly lower levels. In all countries except Vietnam, girls had lower values of 25(OH)D than boys after correcting for age and area of residence. In Thailand and Malaysia, urban children had lower values than rural children (after correcting for age and sex). Age was negatively correlated with 25(OH)D levels (after correcting for sex and urban/rural) in Malaysia and Thailand.

After correcting for age, sex and area of residence, 25(OH)D negatively correlated ($p<0.05$) with BMI and BAZ in Indonesia, Malaysia and Thailand. In Vietnam, a positive correlation ($p<0.05$) was noted between 25(OH)D with BMI and BAZ. Stunted children in Vietnam, but not in the other countries, had 12.4±4.1 nmol/L lower 25(OH)D levels ($p<0.01$) than non-stunted children.

Table 2 gives the percentage of children with deficient, insufficient, inadequate or desirable 25(OH)D levels. A high prevalence of vitamin D deficiency was seen in Vietnam. In contrast, zero prevalence was noted in Indonesia. Insufficient levels were, however, widely prevalent in all countries. In Malaysia, significant differences were noted between ethnic groups. Indians had lower ($p<0.01$) 25(OH)D values (45.6±2.9 nmol/L) than Malays (53.7±1.2 nmol/L) and Chinese (56.2±1.7 nmol/L), after correcting for age, sex and residential area.

Factors related to the level of 25(OH)D in the four countries are presented in Table 3. In all countries, 25(OH)D level was lower at older age but the effect of age was higher in Malaysia compared to Thailand, Indonesia and Vietnam (ns). Urban children had lower 25(OH)D levels, except in Indonesia. Reported time spent doing outdoor activities during the weekend only had an effect on 25(OH)D levels in Thailand. Reported time spent outdoor during weekdays had no effect on 25(OH)D levels in any of the countries. Avoiding sun exposure by protective clothing had an effect in Malaysia but not in the other countries. This parameter was not available in Thailand. In Malaysia and Thailand, an effect of religion on 25(OH)D levels was clearly present, with Hindus in Malaysia and Muslims in Thailand having the lowest 25(OH)D levels. In all countries, there were differences between geographic regions. The range of these differences was as large as 15.0 nmol/L in Indonesia and 33.9 nmol/L in Vietnam.

As seen in Table 4, the variation in mean 25(OH)D per region per country is high with no clear relationship with the average number of daily sunshine hours. For example in Malaysia, Sarawak has the lowest average number of daily sunshine hours but shows the highest 25(OH)D levels. The mean difference between 25(OH)D levels in the Northern and North-Eastern region of Thailand are high with 24.5 nmol/L, whereas the difference in average sunshine hours per day is very small. In Vietnam, the middle region shows much lower 25(OH)D levels which do not coincide with the average number of daily sunshine hours. For Indonesia, data were collected in scattered areas and no reliable information on sunshine hours could be obtained.

Table 5 gives the odds of having inadequate 25(OH)D levels in relation to various factors. Age and being female increased the odds of having inadequate 25(OH)D in all countries except Vietnam. Urban residence (in Malaysia) and specific religions (in Malaysia and Thailand) increased the probability for inadequate levels. The odds of vitamin D inadequacy differed strongly per region in each country.

DISCUSSION

The data presented in this study are representative for the more than 60 million children of that age of the countries in the South-East Asian region. The subsample in this study differed from the total SEANUTS population[27] in age as venous blood was only sampled in older children. The values of the nutritional parameters BMI, HAZ and BAZ however, were not different when compared to the total SEANUTS population of that age.

Crude mean values of 25(OH)D levels were not different between the countries. However, after correcting for age, sex and area of residence, significantly lower values were seen in Indonesian children. The values in the four countries are comparable with the values of 5 to 14 year old Caucasian New Zealand children but noticeably higher than the Maori and Pacific children in New Zealand.[38] A possible reason can be the lighter skin colour of the SEANUTS children as compared to the Maoris and Pacific children. Interestingly, Malaysian children had comparable 25(OH)D values to that reported for Malay adults[39] but Thai children had lower levels than the recent reports on Thai adults.[18]

In Malaysia, Thailand and Indonesia, but not in Vietnam, a higher BMI (or BAZ) was associated with a lower 25(OH)D level. A negative association of 25(OH)D levels with BMI or body fatness is reported in many studies[38,40,41] The positive correlation of 25(OH)D and BMI in

Table 2. Percentage of children with deficient, insufficient, inadequate and desirable 25(OH)D

25(OH)D	Indonesia					Malaysia					Thailand					Vietnam				
	Urban		Rural		All	Urban		Rural		All	Urban		Rural		All	Urban		Rural		All
	Girls	Boys	Girls	Boys		Girls	Boys	Girls	Boys		Girls	Boys	Girls	Boys		Girls	Boys	Girls	Boys	
Deficient	0.0	0.0	0.0	0.0	0.0	9.1	0.7	2.7	0.0	4.1	3.2	0.0	4.5	0.0	2.0	14.7	9.3	10.1	11.5	11.1
Insufficient	45.4	41.7	66.9	31.8	44.0	42.0	38.1	47.7	29.3	39.6	41.0	46.8	32.3	19.3	31.7	42.9	38.4	35.3	36.7	37.1
Inadequate	48.9	49.5	29.9	63.2	50.3	39.0	38.4	40.0	51.9	39.9	53.0	44.8	45.7	47.2	47.2	25.0	41.3	27.9	28.7	29.4
Desirable	5.7	8.8	3.3	5.0	5.6	9.9	22.8	9.7	18.8	16.3	2.8	8.3	17.5	33.5	19.2	17.3	11.0	26.7	23.1	22.4

[†]25(OH)D: 25-hydroxy-vitamin D

[‡]25(OH)D levels are based on chemiluminescence immunoassay in Malaysia and Thailand, HPLC in Vietnam and immunoactivity detection system in Indonesia

[§]Deficient: 25(OH)D <25 nmol/L; insufficient: 25 nmol/L≤25(OH)D level <50 nmol/L; inadequate 50 nmol/L≤25(OH)D level <75 nmol/L; desirable: 25(OH)D ≥75 nmol/L

Table 3. Factors related to 25(OH)D in each country

Parameter	Indonesia			Malaysia			Thailand			Vietnam		
	β	SE	*p*-value	β	SE	*p*-value	β	SE	*p*-value	β	SE	*p*-value
(Intercept)	64.9	4.8	<0.0001	99.4	3.6	<0.0001	74.2	3.7	<0.0001	87.2	9.3	<0.0001
Age (year)	-0.8	0.3	0.017	-3.0	0.3	<0.0001	-0.8	0.4	0.028	-1.1	1.1	0.304
Urban versus rural	0.9	1.6	0.598	-4.4	1.4	0.002	-3.0	1.8	0.099	-2.7	2.8	0.349
Girls versus boys	-5.3	1.6	0.001	-5.9	1.6	<0.0001	-8.2	1.6	<0.0001	0.5	3.0	0.872
Time spent in sun over weekend												
Less than 30 minutes	†			†			-9.2	2.2	<0.0001	†		
Between 30 minutes and 2 hours	†			†			-4.7	2.1	0.023	†		
More than two hours	†			†			Reference group			-		
Screen time (hours)	§			†			-1.4	0.6	0.011	†		
Avoid sun												
by wearing scarf	†			-5.0	1.3	<0.0001	‡			†		
by wearing trousers	†			-2.1	1.2	0.082	‡			†		
Religion												
Islam	‡			Reference group			-7.5	2.9	0.010	‡		
Hinduism	‡			-9.9	2.5	<0.0001	‡		‡	‡		
Christianity	‡			5.1	2.4	0.035	-2.8	3.7	‡	‡		
Buddhism	‡			-0.8	2.2	0.715	Reference group			‡		
Range of regional differences per country (nmol/L)	15.0		<0.0001	23.3		<0.0001	23.8		<0.0001	33.9		<0.0001
R^2 model		0.26			0.47			0.37			0.20	

25(OH)D: 25-hydroxy-vitamin D.

[†]variable was offered but did not enter significantly in model; [‡]variable was not available; [§]variable available but only in small part of the sample.

Table 4. 25(OH)D in various geographical regions by country after correcting for age, sex, area of residence and average yearly sunshine hours per day

Indonesia				Malaysia				Thailand				Vietnam			
Region	25(OH)D (nmol/L)		Average sunshine	Region	25(OH)D (nmol/L)		Average sunshine	Region	25(OH)D (nmol/L)		Average sunshine	Region	25(OH)D (nmol/L)		Average sunshine
	Mean	SE	h/day		mean	SE	h/day		mean	SE	h/day		mean	SE	h/day
Sumatra	64.4	1.9	†	East coast	57.0	1.5	6.9	Central	57.7	1.6	8.1	North	53.6	2.3	6.4
Java	49.3	0.9	†	South	46.6	1.3	7.5	North	45.5	2.2	6.3	Middle	42.6	2.3	6.8
Kalimantan	59.1	2.7	†	North	61.2	1.7	7.5	North-East	69.9	1.4	6.6	South	76.5	3.3	7.3
Sulawesi	63.9	2.6	†	Central	53.4	1.6	7.3	South	52.5	2.4	5.2				
Maluku	57.7	3.8	†	Sarawak	75.6	2.2	6.0	Bangkok	53.1	2.2	5.8				
				Sabah	62.3	1.9	7.1								
All regions	59.1	0.8			58.4	0.7			56.6	0.8			58.2	1.6	

25(OH)D: 25-hydroxy-vitamin D.
†The Indonesian data were collected in too many scattered areas to give reliable information about sunshine hours.

Table 5. Factors determining risk of being vitamin D inadequate (25(OH)D <50 nmol/L) in each country

		Indonesia		Malaysia†		Thailand‡		Vietnam	
		OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
	Age	1.1	1.0, 1.2	1.4	1.2, 1.5	1.1	1.0, 1.2	1.1	0.9, 1.4
	Girls	2.7	1.3, 5.5	1.8	1.0, 3.1	2.2	1.3, 3.7	1.0	0.6, 1.7
	Urban	0.8	0.4, 1.8	1.8	1.1, 3.0	1.1	0.5, 2.2	1.3	0.8, 2.1
Region§	Sumatra vs Sulawesi	2.0	0.4, 10.6	-	-	-	-	-	-
	Java vs Sulawesi	9.6	2.0, 45.0	-	-	-	-	-	-
	Kalimantan vs Sulawesi	3.4	0.6, 20.5	-	-	-	-	-	-
	Maluku vs Sulawesi	4.6	0.5, 39.1	-	-	-	-	-	-
	NE coast vs Sarawak	-	-	3.7	1.4, 9.9	-	-	-	-
	South vs Sarawak	-	-	14.6	5.2, 40.9	-	-	-	-
	North vs Sarawak	-	-	1.6	0.5, 4.7	-	-	-	-
	Central vs Sarawak	-	-	6.3	2.3, 17.4	-	-	-	-
	Sabah vs Sarawak	-	-	2.9	1.1, 7.4	-	-	-	-
	Central vs North-East	-	-	-	-	3.3	1.6, 6.6	-	-
	Northern vs North-East	-	-	-	-	18.8	8.7, 40.3	-	-
	Southern vs North-East	-	-	-	-	4.0	1.7, 9.2	-	-
	Bangkok vs North-East	-	-	-	-	6.3	2.2, 18.0	-	-
	North vs South	-	-	-	-	-	-	3.8	2.1, 7.1
	Middle vs South	-	-	-	-	-	-	14.7	7.6, 28.3
Religion¶	Christian vs Islam	-	-	0.5	0.2, 1.2	-	-	-	-
	Hinduism vs Islam	-	-	4.0	1.3, 12.0	-	-	-	-
	Buddhism vs Islam	-	-	1.0	0.5, 2.2	-	-	-	-
	Islam vs Buddhism	-	-	-	-	3.0	1.2, 7.5	-	-
	Christian vs Buddhism	-	-	-	-	2.1	0.5, 9.5	-	-

25(OH)D: 25-hydroxy-vitamin D; OR: Odds Ratio.
†Taking into account the effects of avoiding sun wearing scarf (ns) and trousers (seldom versus always OR=0.4 (95% CI=0.2, 0.7).
‡Taking into account the effects of screen time (ns) and sun exposure (less than 30 minutes versus >2 hour, OR=2.7 (95% CI=1.3, 5.7).
§In each country the region with the highest 25(OH)D levels is set as reference to obtain OR greater than 1 for the other regions.
¶ The most prevalent religion is set as reference category *i.e.* Islam in Malaysia and Buddhism in Thailand.

Vietnam may be due to the fact that obese children in Vietnam belong to higher socio-economic class and thereby, may have better nutritional intakes.

In Vietnam, but not in the other countries, stunted children had lower 25(OH)D values. This observation fits with the picture of a generally lower nutritional status in stunted children, particularly from lower socio-economic class (results not shown), although it can be argued that exposure to sunshine could compensate for a possible nutritional deficiency. The low fat content in the Vietnamese diet[31] may have contributed to the finding. A positive relationship between 25(OH)D and height has been observed earlier in young women,[42] but to the best of our knowledge there are no previous studies reporting an association between stunting and vitamin D status.

According to this study, there are no vitamin D deficient (25(OH)D <25 nmol/L) children in Indonesia, which could be due to their lower age and thus, possibly higher milk consumption which can contribute to vitamin D intake. In contrast the vitamin D deficiency is much higher in Vietnam than in the other three countries.

In all countries 25(OH)D levels were lower at older age, in urban children (not in Indonesia) and in girls (not in Vietnam). The higher 25(OH)D levels at younger age may be due to a better vitamin D intake, *i.e.* milk intake possibly fortified with vitamin D, in younger children. In Malaysia, younger children were found to be less likely to have vitamin D intakes below the RDA[29] and a notable decrease in the milk intake of Thai and Vietnamese SEANUTS children was seen with age (unpublished results). Higher 25(OH)D values in males than females has been reported by other authors.[18,38,43,44] Differences between urban and rural living areas in 25(OH)D levels and prevalence of vitamin D insufficiency are also known.[18,39]

In Thailand, those who reported spending more time outdoors in the weekend had higher 25(OH)D levels. This was, however, not seen in other countries. One of the reasons for not seeing any relationship between 25(OH)D levels and time spent outdoors may be the general behaviour in tropical countries to avoid direct sunshine. The validity of the information obtained by questionnaire may also be a contributing factor. Cargill et al[45] only found a weak correlation between questionnaire-reported outdoor time and actual sun exposure. In predominantly Muslim Malaysia (but not in Muslim Indonesia) avoiding sun by wearing head scarf or long trousers coincided with lower 25(OH)D levels. This has been reported earlier in Malay adults.[39,44] The fact that this is not found in Muslim Indonesia might be due to less strict religious rules for women to cover the head.

In Malaysia and Thailand, the two countries with different religious population groups, religion seemed to be an important factor. As religion has an influence across all ethnic groups, habits related to religion seemed a better choice than ethnic groups for inclusion in statistics. In Malaysia, Hindus had the lowest 25(OH)D values followed by Muslims. Hindus in Malaysia are mostly ethnic Indians and skin pigmentation[2] could play a confounding role in the observed results. SEANUTS also found lower 25(OH)D levels in Indian children than Malays and Chinese. Indians in Malaysia can be of northern Indian origin (fair skin, predominantly Muslim or Sikh) or southern Indian origin (darker skin colour, more likely to be Hindu). Information about skin colour however, was not available. Ethnic differences in 25(OH)D levels between Malays and Chinese have also been reported in adult women.[46] Islam is the most common religion among the ethnic Malay and to some extent, among Indians. Muslim women are obligated to cover the head with a scarf and to wear long sleeves. Al-Quran states that women are allowed to show only face and hands in public. Therefore, wearing shorts as a Muslim woman is not acceptable. The lower 25(OH)D levels amongst Muslim Thai children may also in part, be attributed to this aspect of Islam.

In all countries the biggest source of variation in 25(OH)D levels were regional (geographical) differences. Interestingly, these large differences between the regions, did not show any relation with average sunshine hours and bringing sunshine hours per day in the statistical model did not lead to significant improvements of the explained variance. There might be various explanations for this. First of all, the actual number of sunshine hours in the region can differ from the yearly average value as provided by meteorological departments. Secondly, the hours of sunshine varies considerably during the year[37] and thus, a yearly average might not indicate a valid possible exposure prior to the study period. Average daily sunshine hours 2 months prior to the actual data collection, however, did not result in a statistical relationship either (results not shown). Seasonal variations in 25(OH)D levels are well known.[38] Thirdly, available sunshine hours do not necessarily mean exposure to it due to staying indoors or in shaded areas or avoiding direct sunshine by wearing clothing or using umbrella. Furthermore, the effectiveness of the sun exposure may differ depending on factors like air pollution, haze and altitude. Fourth, a questionnaire-based approach to gather information may not yield complete or adequate information on all relevant factors that play a role.[45] In this study, we noted several 'missing values' in fields related to use of sun protection cream and therefore, the variable was excluded from analysis. In Vietnam, the few sun protection cream users had 23±7 nmol/L lower 25(OH)D values, but in Malaysia there were no differences between users and non-users. It would be best to measure sun exposure directly using UV sensitive badges and have more detailed information about clothing when being outside. It has to be noted that the sun in tropical countries can be very hot and it is generally unpleasant to be exposed directly, especially when there is no adequate wind chill factor. South-east Asians, especially women, also tended to stay out of the sun in order to maintain a light colour skin, as it is culturally accepted that having fair skin is a mark of beauty.

The differences in 25(OH)D levels per region contributed to vast differences in the chances of being vitamin D insufficient. Results suggest almost 9 times higher odds of residents of Java being vitamin D insufficient as compared to those in Sulawesi (Indonesia) and nearly 19 times higher odds for the Thais in Northern region compared to the North-Eastern region. These regional differences within a country have been observed before in Thailand, where a recent study in adults found variations in 25(OH)D levels across regions but the differences were not as large as in the present study.[18]

Unfortunately there is no adequate information available for all four countries on nutritional intake of vitamin D as the local food composition tables do not contain vitamin D data or many data are missing. For the foods with vitamin D information, data were from a US database and it is questionable whether this is adequate for the South-east Asian region. Given the high prevalence of vitamin D insufficiency this urgently calls for an update on vitamin D content in local foods. The study also shows that the effect of sun exposure cannot be adequately obtained by questionnaire and the use of UV sensitive badges to measure UV-B exposure is needed to collect reliable information. Another known limitation of this study is the use of different 25(OH)D assay methods by the countries. Farrell and Herrmann[47] have reported an acceptable performance characteristics and overall correlation for automated DiaSorin assays and modern HPLC methods (both 25(OH)D_3 and 25(OH)D_2) with the LC-MS/MS reference method. This, to some extent, may justify presenting country-specific vitamin D results in one manuscript. However, in order to draw true comparisons between countries and plan nutrition programs, standardization of 25(OH)D detection methods should be sought. Adequate knowledge of intake data and exposure data using comparable assay methods, next to the aetiological factors as age, sex, area of residence and religion are also necessary to completely understand the wide spread prevalence of poor 25(OH)D levels in sun abundant countries.

In summary

25(OH)D values in South East Asian children are low and the prevalence of vitamin D insufficiency is high, despite an abundance of sunshine. Although sunshine is the most important source for vitamin D, in this study it could not explain the differences in vitamin D status between populations in the same areas. Nutritional vitamin D therefore, becomes very important. Unfortunately no valid information on vitamin D intake for the four countries is available, but data from Malaysia[29] suggests that the total intake is relatively low with many children not reaching the RDA. This points, apart from a general avoidance of sun exposure, to a nutritional problem. Important finding are the large regional differences in 25(OH)D levels in each country, apparently not caused by lack of sunshine. Detailed information about nutritional intake and measured exposure to sunshine is necessary before possible intervention programs can be implemented.

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AUTHOR DISCLOSURES

Friesland Campina sponsored the SEANUTS, but was not involved in the recruitment of the participants, assessments, final set of the results and had no influence on the outcome of the study. The results of the study will be used by Friesland Campina. None of the other authors or the research institutes have any conflicts of interest.

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Original Article

25-hydroxy-vitamin D demography and the risk of vitamin D insufficiency in the South East Asian Nutrition Surveys (SEANUTS)

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东南亚营养调查中 25-羟基维生素 D 人口学特征和维生素 D 缺乏的风险

本课题选择了代表 2010/2011 年在马来西亚、印度尼西亚、泰国和越南进行的东南亚营养调查（SEANUTS）中的 16,744 名年龄在 0.5 到 12 岁之间儿童为样本。使用问卷调查收集了研究对象的社会人口学和行为学信息，同时检测了人体测量学参数。在一个 2016 名儿童的子样本中，测定了血清 25 羟基维生素 D(25(OH)D)浓度。使用 SPSS 软件考虑权重因素的复杂样本分析并报告人群代表性。依据缺乏（<25 nmol/L）、不足（<50 nmol/L），不太足（<75 nmol/L）和充足（≥75 nmol/L）将儿童分类。在马来西亚和泰国，城市儿童 25(OH)D 水平低于农村儿童。在除了越南的其它国家中，男童 25(OH)D 水平高，年龄较大的儿童 25(OH)D 水平低。校正了年龄、性别和居住面积后，地区差异依然存在。在泰国和马来西亚，25(OH)D 水平与宗教有关。有充足 25(OH)D（≥75 nmol/L）儿童所占的百分比从最低的 5%（印度尼西亚）到 20%（越南）。在所有国家，40%到 50%的儿童维生素 D 不足（<50 nmol/L）。Logistic 回归分析显示女孩、城市、农村地区和宗教显著增加维生素 D 缺乏的风险。亚热带 SEANUTS 国家较高的维生素 D 缺乏率，表明需要按各国各地区的具体情况定制解决维生素 D 缺乏问题。促进以食品为基础的积极户外活动的阳光照射策略来提高维生素 D 的摄入是个可行的选择。

关键词：维生素D、25-羟基维生素D、东南亚营养调查、病因