



Vitamin D insufficiency and its contributing factors in primary school-aged children in Indonesia, a sun-rich country

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Purpose: The prevalence of rickets is increasing worldwide in association with an increase in vitamin D deficiency. This study aimed to investigate the vitamin D profile of healthy school-aged children in a sun-rich country and its contributing factors.

Methods: This cross-sectional study was conducted in 120 healthy children from 7–12 years of age who live in Jakarta, Indonesia. Their demographic status, sun exposure duration time, and lifestyle were recorded using a structured questionnaire. Serum calcium, phosphate, bone-alkaline phosphatase (B-ALP), and 25-hydroxy vitamin D (25(OH)₂D₃) levels were measured. The participants were categorized into vitamin D sufficient and non-vitamin D sufficient groups, and we analyzed variables that contributed to the 25(OH)₂D₃ level.

Results: Of the participants, 73 (60.8%) were vitamin D sufficient, 45 (37.5%) were vitamin D insufficient, and 2 (1.7%) were vitamin D deficient. Sex, age, body mass index, Fitzpatrick skin type, daily milk intake, and clothing type were not different between the vitamin D sufficient and non-vitamin D sufficient groups. There were no differences in serum calcium, phosphate, and B-ALP between the 2 groups. Sun exposure time was significantly longer in the vitamin D sufficient group compared with that in the non-vitamin D sufficient group (511.4 min/wk vs. 318.7 min/wk, $P=0.004$), and this effect remained consistent on multivariate analysis after adjustment for covariates (adjusted odds ratio, 1.002; 95% confidence interval, 1.000–1.003). More participants in the vitamin D sufficient group did not use sunscreen (59 vs. 27, $P=0.02$), but this finding was inconsistent with our multivariate analysis.

Conclusion: Despite year-round sun exposure, approximately 1 in 3 primary school-aged children had insufficient vitamin D level. Sun exposure duration was a major contributing factor.

Keywords: Vitamin D deficiency, 25-Hydroxy vitamin D, Rickets, Sun-rich country

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Highlights

- Vitamin D insufficiency is prevalent in Indonesian primary school-aged children despite year-long sunshine.
- Sun exposure duration is a factor of vitamin D sufficiency.
- It is important to ensure adequate vitamin D for children's growth and development.

Introduction

An adequate vitamin D level during childhood has been associated with normal skeletal

growth and development, but limited data exist regarding the extraskelatal benefits of vitamin D.^{1,2)} Severe vitamin D deficiency during the growth period results in nutritional rickets, a disorder of defective growth plate chondrocyte apoptosis and matrix mineralization.¹⁾ The manifestations of rickets vary widely and include both osseous and nonosseous features.¹⁾ Manifestations of the former include wrist and ankle swelling, delayed fontanel closure, delayed tooth eruption, leg deformity, rachitic rosary, and bone pain. Nonosseous features include hypocalcemic seizure, cardiomyopathy, failure to thrive, delayed gross motor development, and high intracranial pressure.¹⁾ Thus, prevention of vitamin D deficiency is important and will contribute to the efforts of fulfilling the third Sustainable Development Goal of ensuring healthy lives and promoting well-being for all.

The target vitamin D level is controversial, and recommendations for a sufficient vitamin D level vary widely.^{1,3,4)} In 2016, the Global Consensus Recommendations on Prevention and Management of Nutritional Rickets¹⁾ was published as universal guidance to prevent rickets. Based on the Global Consensus, serum vitamin D level (25(OH)₂D₃) > 20 ng/mL (50 nmol/L) is sufficient to prevent rickets in children and adolescents.

The prevalence of vitamin D deficiency is considered high throughout the world, even in sun-rich countries, and ranges from 1%–95% relative to the threshold used to define vitamin D deficiency.^{2,4-9)} The high prevalence of vitamin D deficiency in sun-rich countries has been attributed to limited sun exposure and a sedentary lifestyle, whereas laxity in fortified food and geographical latitude have been considered significant contributing factors in four-season countries.⁴⁾

Even though Indonesia lies on the equator with year-long sunlight exposure, changes in lifestyle towards more indoor and sedentary activities, consumption of more sweetened beverages, lack of vitamin D-fortified food, and air pollution increase the risk of vitamin D deficiency and its skeletal consequences. The South East Asian Nutrition Surveys (SEANUTS) study¹⁰⁾ showed that just 5.6% of respondents in Indonesia had desirable vitamin D level, whereas only 16.3%, 19.2%, and 22.4% of participants in Malaysia, Thailand, and Vietnam had desirable vitamin D level, respectively. There were no participants from Indonesia who had vitamin D deficiency.¹⁰⁾ Until recently, there have been no reports of data on the vitamin D levels of healthy school-aged children in Indonesia; thus, we aimed to investigate the vitamin D profile in healthy school-aged children and any factors that contributed to their vitamin D status.

Materials and methods

This was a cross-sectional study conducted in 120 healthy children from 7–12 years of age from a public primary school and an Islamic private primary school in Jakarta, Indonesia, in 2012. Informed consent was obtained from the children's legal guardians. This study was ethically approved by the Institutional Review Board of the Faculty of Medicine Universitas Indonesia/Cipto Mangunkusumo General Hospital in Jakarta, Indonesia.

We excluded participants who were known to have liver diseases and malabsorption syndromes or who were prescribed glucocorticoids, anticonvulsants, or antituberculosis treatment. We also excluded patients with a history of acute illnesses within the 2 weeks before this study began.

Age, sex, socioeconomic status, clothing style, sunscreen usage, sun exposure duration, and milk and juice intake were obtained using a structured self-report questionnaire by the children's legal guardians during the recruitment phase. We classified the children's skin color using the Fitzpatrick skin phototype classification, which was based on the skin's response to ultraviolet light.¹¹⁾ The skin types are as follows: type I=very pale skin, burns very easily, never tans; type II=fair skin, burns easily, rarely tans; type III=fair/light brown skin, sometimes burns, gradually tans; type IV=medium to dark brown skin, hardly ever burns, tans very easily; type V=dark brown skin, rarely burns, tans easily and quickly; type VI=black skin, never burns, tans deeply.¹¹⁾ The children's socioeconomic status was assigned based on their parents' occupations. We calculated total sun exposure duration as min/wk based on the average duration of sun exposure in a day. The participants' clothing style was expressed as long/short sleeves and long/short pants/skirts. The nutritional status of the participants was measured by calculating the body mass index (BMI). The weight and height of the participants were assessed using a standard protocol, and BMI was calculated as the weight (kg)/height² (m²). Nutritional status was classified based on the Centers for Disease Control and Prevention 2000 BMI growth chart as follows: underweight <5th percentile, normal 5th–85th percentile, overweight 85th–95th, and obese >95th percentile.¹²⁾

1. Measurement of vitamin D level

Ten milliliters of blood were collected from each participant to measure serum calcium, phosphate, bone-alkaline phosphatase (B-ALP), and 25-hydroxy vitamin D (25(OH)₂D₃) levels. The 25(OH)₂D₃ level was determined using radioimmunoassay methods (DiaSorin, Saluggia, Italy), while B-ALP was obtained using a MetraBAP kit (OSTEO Medical Partner). Serum 25(OH)₂D₃ ≥20 ng/mL was considered sufficient, 12–20 ng/mL was regarded as insufficient, and ≤12 ng/mL was labeled deficient.¹⁾

2. Statistical analysis

Bivariate analysis was performed based on vitamin D level, and participants were categorized into sufficient and nonsufficient groups. The nonsufficient group included participants with insufficient or deficient vitamin D level. Group differences were estimated and tested using an independent group *t*-test, a chi-square test, or a Fisher exact test where appropriate, and *P*-values were provided. Continuous variables were expressed as mean and standard deviation or median and interquartile range if the distribution was skewed. Categorical

variables were expressed as n (%). Variables with a *P*-value <0.05 were considered statistically significant, and these variables were analyzed further to determine their association with vitamin D level. Multivariable logistic regression that had been adjusted for covariates was performed to examine the association between contributing factors with 25(OH)₂D₃ levels. Age, sex, BMI, and clothing style were considered possible covariates. Statistical analyses were conducted using the IBM SPSS Statistics ver. 24.0 for Mac (IBM Co., Armonk, NY, USA).

Results

There were 75 girls of the 120 total participants included in this study, and they had a mean age of 9.6 years. All our participants were Southeast Asian (100%). Around half of the children's parents worked at private companies, and 29 of 120 participants were students at a public primary school. Approximately 65.8% had a normal BMI, and 25% were overweight or obese. Of all participants, 73 (60.8%) had sufficient vitamin D, and only 2 (1.7%) had a vitamin D

deficiency. There were 45 children (37.5%) with vitamin D insufficiency (Table 1).

Sex, age, BMI, nutritional status, Fitzpatrick skin type, daily milk intake, and clothing type were not different between the vitamin D sufficient and nonsufficient groups. The sun exposure time was significantly longer in the vitamin D sufficient group (511.4 min/wk vs. 318.7 min/wk, respectively, *P*=0.004) compared with that in the nonsufficient group (Table 2). More participants in the sufficient group did not use sunscreen (59 participants vs. 27 participants, *P*=0.02). Serum calcium, phosphate, and B-ALP levels were not different between the groups.

Multivariate analysis showed that sun exposure duration was consistently associated with vitamin D level after adjustment for several potential covariates, with an adjusted odds ratio (OR) of 1.002 (95% confidence interval [CI], 1.000–1.003), whereas sunscreen use was not significantly associated with vitamin D level (Table 3).

Discussion

In this cross-sectional study, we identified a notable proportion of vitamin D insufficiency cases in healthy primary school-aged children in Indonesia, a sun-rich country, and factors associated with serum vitamin D level. Despite the year-round availability of sunlight, our study showed 47 of 120 children (39.17%) were vitamin D insufficient, including 2 participants with vitamin D deficiency. We found sun exposure duration to be the only factor that consistently contributed to vitamin D level.

Despite differences in the study age groups, the mean vitamin D level in our study was similar to that reported for the Indonesian cohort of the SEANUTS study¹⁰: 21.9 ng/mL vs. 21.1 ng/mL. Our study only included primary school children from 7–12 years of age with a mean age of 9.6 years, while the SEANUTS study¹⁰ included Indonesian children from 0.5–12 years old with a mean age of 6.6 years. The participants in our study consisted entirely of urban children living in a large city, while in the SEANUTS study,¹⁰ a rural population was included. Compared to other countries in the SEANUTS study, Indonesian children had a significantly lower mean level of vitamin D.¹⁰ A lack of awareness about vitamin D and the importance of sun exposure for vitamin D synthesis might explain the low vitamin D levels in Indonesian children.

As Southeast Asia is a tropical region, sunlight is available year-round, with little to no variance of daylight hours. Nevertheless, a high prevalence of vitamin D deficiency has been reported in this region.¹³ The notable proportion of vitamin D insufficient children in our study (39.17%) is consistent with the findings of the SEANUTS study, where only 5.6% of the Indonesian participants (both urban and rural) had adequate vitamin D level.¹⁰ Behavioral factors might contribute to vitamin D deficiency in Indonesia, where avoiding the sun is generally the norm. Sun-avoiding behaviors, such as staying in the shade, using an umbrella as

Table 1. Subject characteristics

Variable	Male (n=45)	Female (n=75)
Age (yr)	9.34±1.49	9.74±1.53
Ethnicity		
Southeast Asian	45 (100)	75 (100)
Parents' occupations		
Civil servants	3 (6.7)	4 (5.3)
Private companies	23 (51.1)	32 (42.7)
Entrepreneur	10 (22.2)	26 (34.7)
In the army/police force	2 (4.4)	1 (1.3)
Physician/nurse	2 (4.4)	0 (0)
Homemaker	0 (0)	7 (9.3)
Retired	0 (0)	1 (1.3)
Unknown	5 (11.1)	4 (5.3)
Public/private school		
Public school	7 (15.6)	22 (29.3)
Private school	38 (84.4%)	53 (70.7)
BMI (kg/m ²)	18.90±4.08	17.19±3.37
Nutritional status based on BMI percentiles		
Undernourished	3 (6.7)	8 (10.7)
Normal	25 (55.6)	54 (72.0)
Overweight	8 (17.8)	7 (9.3)
Obese	9 (20.0)	6 (8.0)
Fitzpatrick skin type		
III	8 (17.8)	20 (26.7)
IV	37 (82.2)	55 (73.3)
Vitamin D (ng/dL)	22.16±6.01	21.67±6.57
Vitamin D status		
Sufficient	29 (64.4)	44 (58.7)
Insufficient	15 (33.3)	30 (40.0)
Deficient	1 (2.2)	1 (1.3)

Values are presented as mean±standard deviation or number (%). BMI, body mass index.

Table 2. Factors contributing to vitamin D status

Variable	Nonsufficient (n=47)	Sufficient (n=73)	P-value
Female sex	31 (65.9)	44 (60.3)	0.53 [†]
Age (yr)	9.7±1.3	9.5±1.7	0.65 [‡]
BMI (kg/m ²)	18.6±4.1	17.4±3.4	0.09
Nutritional status based on BMI percentiles			0.15 [†]
Undernourished	2 (4.3)	9 (12.3)	
Normal	29 (61.7)	50 (68.5)	
Overweight	9 (19.1)	6 (8.2)	
Obese	7 (14.9)	8 (11.0)	
Fitzpatrick skin type IV	32 (68.1)	60 (83.2)	0.08 [†]
Parents' occupations			0.74 [†]
Civil servants	2 (4.3)	5 (6.8)	
Private companies	23 (48.9)	32 (43.8)	
Entrepreneur	11 (23.4)	25 (34.2)	
In the army/police force	1 (2.1)	2 (2.7)	
Physician/nurse	1 (2.1)	1 (1.4)	
Homemaker	4 (8.5)	3 (4.1)	
Retired	1 (2.1)	0 (0)	
Unknown	4 (8.5)	5 (6.8)	
Public/private school			0.142 [†]
Public school	8 (28)	21 (72)	
Private school	37 (40)	54 (59)	
Sun exposure (min/wk)	318.7±286	511.4±355	0.004 [‡]
No sunscreen used	27 (57.4)	59 (80.8)	0.02 [†]
Daily milk intake (mL/day)	325±268	327(250)	0.97 [‡]
Type of clothing			0.28 [†]
Long sleeves	10 (4.3)	59 (80.8)	
Long trousers/skirts	17 (36.2)	22 (30.1)	
Calcium level (mg/dL)	9.50±0.32	9.46±0.39	0.51 [‡]
Phosphate level (mg/dL)	4.73±0.44	4.64±0.47	0.33 [‡]
B-ALP (mg/dL)	164.9±40.7	172.2±59.4	0.47 [‡]

Values are presented as number (%) or mean±standard deviation.

BMI, body mass index; B-ALP, bone-alkaline phosphatase.

[†]Chi-square test. [‡]Independent t-test.

Table 3. Univariate and multivariate analysis of factors contributing to vitamin D status

Variable	Univariate analysis		Multivariate analysis	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Male sex	1.277 (0.595–2.742)	0.531	1.099 (0.453–2.664)	0.835
Age	0.944 (0.741–1.203)	0.643	0.835 (0.626–1.115)	0.257
Body mass index	0.919 (0.832–1.015)	0.094	0.908 (0.811–1.017)	0.095
Fitzpatrick skin type III, III vs. IV	0.462 (0.196–1.090)	0.078	0.565 (0.211–1.517)	0.257
Sun exposure (min/wk)	1.002 (1.000–1.003)	0.006*	1.002 (1.001–1.003)	0.004*
No sunscreen used, no vs. yes	0.928 (0.837–1.028)	0.122	0.917 (0.820–1.025)	0.084

OR, odds ratio; CI, confidence interval.

*P<0.05, statistically significant difference.

sun protection, and choosing indoor activities, are common. Although we found no significant difference in type of clothing worn between vitamin D insufficient and vitamin D sufficient children, cultural norms, such as wearing long sleeves, long skirts, and headscarves in Muslim women also could contribute to minimized sun exposure and lead to insufficient vitamin D level.¹⁴⁾ The private school where the majority of our

participants were students was an Islamic private school, so all girls wore hijabs (long sleeves, long skirts, and headscarves). We identified 2 children with vitamin D deficiency. Upon closer inspection of the characteristics of these 2 participants, no notable differences were found for all parameters. Further interviews and examinations were needed to investigate these deficiencies, so these children were recommended for a referral

to a pediatrician.

It is known that the major source of vitamin D is the skin via its absorption of sunlight,^{4,15} but many other factors also contribute to a person's level of vitamin D, including BMI,¹⁶⁻¹⁸ the season of the year, latitude, time of day, skin pigmentation, skin area exposed, and sunscreen use. Air pollution, haze, and altitude are also contributing factors, as these can alter the potency of the ultraviolet B (UVB) radiation.¹⁹

Our study found that the amount of time spent in the sunlight was the only factor that contributed to the vitamin D level in the body. The duration of time spent in the sunlight in the vitamin D sufficient group was significantly longer than that spent by the nonsufficient group. However, we did not find any clear association of sunscreen, clothing type, or BMI with vitamin D level. Obese children and adolescents have lower vitamin D level compared with their nonobese counterparts, and a 1% increase in fat weight is associated with a 0.46 ± 0.2 ng/mL (1.15 ± 0.55 nmol/L) reduction in the serum $25(\text{OH})_2\text{D}_3$ level.¹⁶ Some studies have revealed that serum $25(\text{OH})_2\text{D}_3$ level demonstrates a strong inverse correlation with fat volume and a weaker inverse correlation with BMI.^{17,18} No clear mechanism exists for why the $25(\text{OH})_2\text{D}_3$ concentration is decreased in the obese population, but it is hypothesized that adipose tissue absorbs fat-soluble vitamin D.¹⁶⁻¹⁸ Our relatively small study size was likely responsible for not finding a significant BMI difference between the sufficient and nonsufficient groups.

A person's skin phototype might contribute to vitamin D level, but we found no significant relationship between these variables in our study. We observed darker-skinned subjects (Fitzpatrick phototype IV) to be mostly vitamin D sufficient, despite some literature showing that darker skin can contribute to low vitamin D level due to dark skin containing higher amounts of melanin.²⁰ In the Indonesian children we studied, a darker skin phototype might be due to lifestyle (e.g., more outdoor activities and more sun exposure), which might explain their vitamin D sufficiency. With regard to ethnicity, we classified all participants as Southeast Asian, although they were of different Indonesian tribal descent. Indonesia is a large archipelago country with hundreds of ethnic tribes; our sample consisted of children of Javanese and Betawi descent, 2 majority tribes in the island of Java (where Jakarta is located).²¹ The 2 tribes are similar genetically and have been found to be of the same haplogroup; thus, we classified all our participants in the same ethnic group.^{21,22}

The re-emergence of rickets in children and adolescents during the last decade has resulted in increased awareness of vitamin D status worldwide.^{1-3,19} The global consensus recommendation¹ uses the same threshold as the Pediatric Endocrine Society¹⁹ and the American Academy of Pediatrics¹⁹ to define vitamin D status. In children and adolescents, sufficiency is a $25(\text{OH})_2\text{D}_3$ threshold >20 ng/mL (50 nmol/L). One vital question that remains to be answered is whether or not the current vitamin D requirements are appropriate for all children or if the requirements should be tailored based on moderating factors, such as age, race, and/or latitude.¹⁹ The

primary source of vitamin D is cutaneous exposure to solar UVB radiation,^{3,11} but there are no global guidelines on the amount of safe sun exposure required to achieve adequate vitamin D level in children and adolescents.^{19,23} There are guidelines available for some lower northern-latitude countries but not in many other parts of the world.^{19,23} This dearth of recommendations is most apparent when comparing $25(\text{OH})_2\text{D}_3$ levels in children who live in distinct geographical locations.¹⁹

A substantial number of studies performed prior to the 2016 Global Consensus Recommendation included a higher threshold to assign a vitamin D sufficiency status. Vitamin D level was considered sufficient when $25(\text{OH})_2\text{D}_3$ level is >30 ng/mL.^{4,6-10,15} Using this old threshold, studies by Khor et al.⁷ and Bener et al.⁴ showed a higher prevalence of vitamin D deficiency (35.3% vs. 28.9%). Similar results were obtained in Qatar and Saudi Arabia.^{8,15} In contrast, our study showed a substantially lower prevalence of vitamin D deficiency in primary school-aged children (1.7%). This relatively large difference in prevalence is probably due to the difference in the vitamin D threshold used in our study.

Compared with other previous cross-sectional studies in Indonesia, our study had a more homogenous population of primary school-aged children.^{4,6,8} This population subgroup tended to be more active and spent more time outdoors compared with older children or adolescents. One of the strengths of our current study was that there were no missing data from the questionnaire or laboratory results. We recognize that our study size is too small to statistically detect all associations between all possible contributing factors with serum vitamin D level. The questionnaire-based approach that we used in this study can lead to misclassification and recall bias, although we believe that if any occurred, it was random. Direct measurement of sun exposure using ultraviolet-sensitive badges can be a reliable tool to measure sun exposure objectively.²⁴ Unfortunately, this tool is currently unavailable in Indonesia, so we used alternative methods. Another limitation of our study was its minimal exploration of the socioeconomic status of our participants. Socioeconomic status can be a contributing factor in vitamin D deficiency.^{25,26} Our questionnaire only included questions about the parents' occupations; therefore, our data were inadequate to infer the children's socioeconomic status. Our participants included students of a public primary school and a private primary school, which could suggest the students' socioeconomic status. Public primary schools are free and mostly enroll children of blue-collar workers who might have an unstable income, while private schools (especially the one included in our study) charge sizeable tuition fees and attract more white-collar families. Our population included a large difference in number of children from public and private schools, which made comparisons inappropriate. The smaller number of public school students included in our study sample was due to the small number of students who returned informed consent forms and our difficulties with contacting parents. Therefore, no conclusions can be made on the influence

of socioeconomic status on vitamin D level in our study. Further studies need to explore socioeconomic parameters (such as monthly income and parents' formal education levels) to provide more information on how these factors contribute to children's vitamin D level.

Studies on vitamin D sufficiency in children and adolescents are valuable to develop regional guidelines to warrant vitamin D adequacy in these vulnerable populations. The strategies adopted to ensure vitamin D adequacy will differ between sun-rich and non-sun-rich countries.¹¹⁾ To achieve vitamin D sufficiency in the absence of sun exposure, children must ingest foods that contain vitamin D (either natural or via fortification) and/or vitamin D supplements, whereas in sun-rich countries, guidance for a safe sunlight exposure amount is needed. An effective public health approach to increase sunlight exposure, address sun avoidance, and promote food-based strategies to reach optimal vitamin D status are of paramount importance.

In summary, our study found that approximately one in 3 primary school-aged children in Indonesia, a sun-rich country, was vitamin D insufficient despite year-round sun exposure. Sun exposure duration is a major contributing factor to vitamin D sufficiency. Efforts should be made to estimate the adequate UVB exposure required to meet the suggested 25(OH)2D3 thresholds in children and whether food fortification with vitamin D can be an alternative solution to ensure adequate vitamin D level.

Ethical statement

This study was ethically approved by the Institutional Review Board of the Faculty of Medicine Universitas Indonesia/Cipto Mangunkusumo General Hospital in Jakarta, Indonesia. (IRB no. 090/UN2.F1/ETIK/PPM.00.42/2011)

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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