A cross-sectional assessment of prevalence and risk factors-mediating hypovitaminosis D in 6-12-year-old school-going children in Highlands of Southern-Western Ghats, India

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Abstract

Introduction: Several global epidemiological and public health interventions demonstrated that deficiency of vitamin D in children has negative associations with health. However, limited data are available on vitamin D status among children living in high-altitude regions.

Objectives: To assess the vitamin D status and risk factors among 6-12 year old children residing in the selective high-altitude regions in Southern India.

Method: A regional-based cross-sectional survey was performed on 102 participants with a validated questionnaire. The survey collected the details of physical health, anthropometry, dietary habits, socioeconomic status (SES), skin colour, and sunlight exposure. In addition, a blood sample was collected from each participant and analysed to assess the serum vitamin D, parathyroid hormone, calcium, and phosphorus levels.

Results: More than 80% of the sampled 102 participants of 6-12 year aged children living in the highlands (1800 metres above mean sea level) of Southern-Western Ghats, India, had insufficient levels of vitamin D; 42% of children had vitamin D insufficiency and 40% had vitamin D deficiency. Variables such as joint pain [$x(1)$= 36.573, p=0.001], weakness and tiredness [($x(1)$=65.713, p=0.001], growth [$x(1)$=5.474, p=0.02], cough and cold [$x(1)$=34.563, p=0.039], leg and back pain [$x(1)$=65.707, p=0.001], showed significant association with the vitamin D levels. A weak positive correlation between phosphorus, calcium and vitamin D levels and a weak negative correlation between weight and vitamin D were also observed.

Conclusions: Majority of children of the 6-12 year age group living in the highlands of Southern-Western Ghats, India had vitamin D deficiency. Our findings indicated that lower socioeconomic status and inadequate consumption of vitamin D rich foods were the potential risk factors mediating vitamin D deficiency in children in the high altitude regions.

(Key words: Vitamin D deficiency, Children, Sun exposure, Malnutrition, Socioeconomic status)

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Introduction

Classically, vitamin D (Vit. D) plays an essential role in maintaining bone strength by modulating calcium and phosphorus metabolism[1]. Its deficiency is associated with the demineralization of bones and rickets in children. Several other beneficial Vit.D functions have been newly postulated[2]. Active monitoring of Vit.D status through public health programmes has been enacted by various countries, including India, to identify the vulnerable population and support them through dietary or therapeutical approaches[3,4].

Vit.D deficiency (VDD) is prevalent in infants, school children, pregnant and lactating women and older adults of low socioeconomic status (SES) in India[4-6]. Likewise, VDD is endemic in the highlands due to socioeconomic factors, lifestyles, and environmental constraints[4,7,8]. Likely, challenged exposure to sunlight due to short span of sunny weather, SES of tribal population, and malnutrition of dietary Vit.D in Southern-Western Ghats of India further worsen cutaneous synthesis of pre-vitamin D_3. Hence children inhabiting highlands (1500 metres above mean sea level) of under privileged SE populations of Southern India could be hypothesized as vulnerable to VDD. However, scientific assessments of Vit.D status in children living in high-altitude regions of Southern India are scarce.

Objectives

To evaluate the prevalence of VDD and determine the risk factors among 6-12 year old school-going children in selected areas of Southern-Western Ghats, India.

Method

A total of 112 children of both sexes, aged 6-12 years, inhabitants at the altitude of 1800-2200 metres mean sea level in the randomly selected regions of Kotagiri, Kadasolai, and Sholurmattam were enrolled for the survey. Study sites were in the Southern-Western Ghats, in the following global positioning system coordinates, Kotagiri: 11.4218°N, 76.8617°E, Kadasolai: 11.4702°N, 76.6714°E; Sholurmattam: 11.2632°N, 76.5658°E. Study was conducted in the primary care centres in the study locations during spring and summer months in 2021. The general practitioner (GP) conducted the clinical examination and confirmed that the participants met the inclusion criteria.

Inclusion criteria: Healthy male and female 6-12 year old children who were inhabitants in the highlands, 1500 metres above mean sea level of Southern-Western Ghats, India were recruited for the study.

Exclusion criteria: Children suffering from chronic health conditions, endocrine disorders, skin disorders, and other systemic illness.

Procedure: One hundred and twelve children in the age group of 6-12 years were preliminarily screened for their health status by the GP. Of them, six were diagnosed with heart disorders and four had skin disorders. They were excluded from the study. The remaining 102 healthy children were recruited for the assessment of the vitamin D status. Further, the survey questionnaire was validated with a pilot survey conducted among children and parents. The GP and paediatrician scrutinized the study questionnaire and protocol.

Sample size: This was calculated using G-power-3-software. Mean and standard deviation (SD) from a similar study was considered, and the value of the effect size (d), level of significance (α), and power (1-β) was fixed. Effect size was calculated as d=0.5, level of significance α=0.05, and power as 80%. A sample of 102 subjects was obtained after calculation. Sample size was adjusted for dropout rate (approximately 20%) during study.

Survey instrument: A questionnaire was prepared in English and administered online (through Google forms) to 1/3rd of the targeted sample size of children living in the study region. Data collected in the preliminary analysis were used to validate the questionnaire. Further, a validated semi-structured questionnaire was administered to collect demographic and study-specific information. All survey questionnaires were administered in person directly with the study participants by study investigators along with the clinical team.

Study participants' SES was assessed using the modified-Kuppuswamy SES scale[9]. Time duration of participants' physical activities and exposure to sun was surveyed. Physical activity level for each subject was calculated using standard methodology[10]. Clothing of participants during various outdoor activities was assessed, and the total exposure period in hours and body area (percentage) under direct sunshine was documented[7]. Food frequency questionnaire was used to collect subject's dietary profile and dietary consumption pattern of foods. Food was divided into two categories vegetarian and non-vegetarian sources of Vit.D. Frequency of consumption of Vit.D-rich food sources by subjects was collected. Frequency of consumption of butter, yogurt, milk, juice, mushroom, cereal, cheese, and tofu was assessed as the vegetarian diet rich in Vit.D. Dietary frequency of egg, salmon, shrimp and fish were considered as non-vegetarian food containing Vit.D. Also, any dietary supplementation of fish, cod liver oil and vitamins were surveyed among participants.

Skin colour assessment: Skin colour was assessed based on the Indian skin colours and previous studies conducted in India. The reason for the assessment of skin colour was that dark human skin absorbs more ultraviolet B radiation in the melanin of their skin than light colour skin does and, therefore, needs more sun exposure to produce the same amount of vitamin D. Higher amounts of the melanin in the epidermal layer result in darker skin and reduce the skin's ability to produce vitamin D from sunlight. So, based on previous studies, Fitzpatrick scale was used to measure the skin colour which includes dark brown, light brown and pale white.

Anthropometric profile: Clinical height chart and a calibrated weighing machine (SECA 813) measured the heights and weights of participants, respectively. A standard adjustment to the nearest 1mm or 0.1 kg for height and weight was applied. Investigator ensured that participant's height was measured standing barefoot and not wearing heavy clothes during weight measurement.

Clinical examination: The GP examined the subjects for any clinical signs and symptoms of VDD. Subjects were asked to walk and limb movements observed to diagnose bowlegs and knock-knees. Wide wrists and rachitic rosary were also observed.

Biochemical profile: A phlebotomist withdrew 3ml blood from the median cubital vein of each participant. The samples were then centrifuged within 2 hours at Biotech lab, Kotagiri and serum samples were stored at −20°C until transportation to the Thyrocare Laboratory, Coimbatore, India. All parameters were measured via standard research laboratory procedures ('BECKMAN ACCESS 2 autoanalyzer) in Thyrocare Laboratory, Coimbatore. Biochemical estimation of serum Vit.D and parathyroid hormone (PTH) were done using fully automated chemiluminescent immunoassay. Endocrine Society categorization was applied to classify vitamin D status among children. Serum Vit.D levels of 30 ng/ml and above, 21–29 ng/ml, and <20 ng/ml were classified as vitamin D sufficient, insufficient, and deficient. Likewise, the normal reference range of PTH in young children was 12 - 80 pg/ml, but reference range varied based on estimation method[11]. Calcium estimation was done using photometry Arsenazo III method, and calcium level between 8.8-10.6 mg/dl was taken as normal. Phosphorus estimation was done by phosphomolybdate methodology semi-automated assay, and reference range was 4.0-7.0 mg/dl.

Ethical issues: Ethics approval was given by the Institutional Review Board of JSS College of Pharmacy, Ooty, Tamil Nadu, India (No JSSCP/IRB/01/2019-20). Prior permission for the conduct of the study at the selected study regions was obtained from the tribal centre, Kothagiri; Before initiating study, parents were informed about survey and sufficient time was provided to decide on participation. Voluntary written consent was obtained from parents before administering survey questionnaire. They were informed that they could withdraw from any stage of survey and that their identity would remain anonymous.

Statistical analysis: Descriptive analysis was performed for demographic characteristics. Continuous variables were illustrated as mean ± SD, while categorical variables were expressed as percentages. For normally distributed data, parametric tests were used to measure the differences in variables among groups. Independent t-test and Chi-square test were used for continuous variables and categorical variables, respectively. Pearson's correlation analysis investigated association between serum Vit.D levels and other participants' demographic characteristics. All analyses used the IBM-SPSS-statistical-software (V.22.0;SPSS Inc,Chicago,Illinois,USA).

Results

Demographic profile is presented in Table 1A. Of the 112 children enrolled in study 10 were excluded as six had heart surgery and 4 had skin disorders.. Participants were from Kotagiri, Solurmattam, and Kadasolai of Nilgiris District, Tamil Nadu, India. Table 1B shows the findings on clinical examination by GP.

Table 1A
Study participants' demographic profile (n=112)

Demographic characteristic	n (%)
Participants	
Included	102 (91.1)
Excluded	10 (08.9)
Location	
Kotagiri	36 (35.3)
Solurmattam	41 (40.2)
Kadasolai	25 (24.5)
Gender	
Male	51(50. 0)
Female	51 (50.0)
Age group	
6-9	44 (43.1)
10-12	58 (56.9)
Socioeconomic status	
Upper	0 (0)
Upper middle	14 (13.1)
Lower middle	23 (22.5)
Upper lower	60 (58.8)
Lower	05 (04.9)
Skin colour	
Dark brown	34 (33.3)
Light brown	64 (62.7)
Pale white	04 (03.9)

Table 1B
Study participants' clinical profile (n=102)

Physical examination	n (%)
Bow Legs	03 (02.9)
Knock knees	01 (0.9)
Wide wrists	05 (04.9)
Rickety rosary	02 (01.9)

Anthropometric measures, blood VDD biomarkers and gender-categorized data of participants are presented in Table 1C. Data analysis revealed that 18 (17.6%) children had Vit.D-sufficiency, 43 (42.2%) had Vit.D-insufficiency, and 41 (40.2%) had severe VDD. Age, height, weight, Vit.D, PTH, calcium, and phosphorus had no gender-specific differences (p>0.05).

Table 1C: *Study participants' anthrophometry and clinical biochemistry profile*

Variable	All (Mean±SD)	Male (Mean±SD)	Female (Mean±SD)	*p*
Height (cm)	132.3 ± 11.7	133.9 ± 12.8	130.9 ± 13	0.19
Weight (kg)	26.6 ± 6.9	27.2 ± 7.6	25.9 ± 6.0	0.38
Age (years)	9.7 ± 1.9	9.7 ± 1.9	9.6 ± 1.6	0.74
25-hydroxy Vitamin D (ng/ml)	22.2 ± 7.8	21.6 ± 6.5	22.8 ± 8.9	0.43
Parathyroid Hormone (pg/ml)	29.3 ± 22.4	26.9 ± 24.1	31.7 ± 20.4	0.28
Calcium (mg/dL)	9.4 ± 0.6	9.3 ± 0.7	9.52 ± 0.4	0.11
Phosphorus (mg/dL)	4.9 ± 0.5	4.9 ± 0.6	4.8 ± 0.5	0.83

Chi-square test was used to find the association between Vit.D levels and other demographic variables of study participants (Table 2). Variables such as location of study participants, SES and colour of skin showed significant association between Vit.D levels and demography. Gender and age did not show any association.

Table 2: ***Association of vitamin D levels with study participants' demographic profile***

Parameter	Vit D deficiency (<20 ng/ml) n (%)	Vit D insufficiency (>20<30ng/ml) n (%)	Vit D sufficiency (>30 ng/ml) n (%)	95% CI	*p*
Location					
Kotagiri	08 (22.2)	15 (41.7)	13 (36.1)	0.001-	0.001
Solurmattam	17 (41.5)	19 (46.3)	05 (12.2)	0.0029	
Kadasolai	16 (64.0)	09 (36.0)	0 (0.0)		
Gender					
Male	21 (41.2)	23 (45.1)	7 (13.7)	0.279-	0.284
Female	20 (39.2)	20 (39.2)	11 (21.6)	0.466	
Age group (years)					
6-9	12 (27.3)	23 (52.3)	09 (20.5)	0.007-	0.066
10-12	29 (50.0)	20 (34.4)	09 (15.5)	0.091	
Socioeconomic status					
Upper middle	01 (07.1)	03 (21.4)	10 (71.4)		
Lower middle	09 (39.1)	11 (47.8)	03 (13.0)	0.001-	0.001
Upper lower	28 (46.7)	27 (45.0)	05 (8.3)	0.029	
Lower	03 (60.6)	02 (40.0)	0 (0.0)		
Skin colour					
Dark brown	17 (50.0)	14 (41.2)	03 (08.8)		
Light brown	24 (37.5)	29 (45.3)	11 (17.2)	0.001-	0.001
Pale white	0 (0.0)	0 (0.0)	04 (100.0)	0.029	

Table 3 shows that joint pains, feeling weak and tired, growth, cough and cold, leg and back pain showed significant association with Vit.D levels.

Table 3: ***Association of vitamin D levels with study participants' physical health***

Parameter	Vit D deficiency (<20 ng/ml) n (%)	Vit D insufficiency (>20<30ng/ml) n (%)	Vit D sufficiency (>30 ng/ml) n (%)	95% CI	*p*
Bow legs					
No	38 (38.4)	43 (43.4)	18 (18.2)	0.007-	0.088
Yes	03 (100.0)	0 (0.0)	0 (0.0)	0.091	
Knock knees					
No	40 (39.6)	43 (42.6)	18 (18.2)	0.393-	0.490
Yes	01 (100.0)	0 (0.0)	0 (0.0)	0.587	
Wide wrists					
No	37 (38.1)	42 (43.3)	18 (18.6)	0.048-	0.108
Yes	04 (80.0)	0 (0.0)	0 (0.0)	0.168	
Rickety rosary					
No	39 (39.0)	43 (43.0)	18 (18.0)	0.111-	0.186
Yes	02 (100.0)	0 (0.0)	0 (0.0)	0.262	
Joint pain					
Rare	16 (84.2)	02 (10.5)	01 (05.3)	0.001-	
Sometimes	14 (35.0)	25 (62.5)	01 (02.5)	0.029	0.001
Frequent	11 (25.6)	16 (37.2)	16 (37.2)		
Quick fall					
Rare	02 (100.0)	0.(0.0)	0 (0.0)	0.102-	0.176
Sometimes	39 (39.0)	43 (43.0)	18 (18.0)	0.250	
Weak and tired					
Rare	03 (15.8)	02 (10.5)	14 (73.7)	0.001-	0.001
Sometimes	21 (33.9)	37 (59.7)	04 (22.2)	0.029	
Frequent	17 (81.0)	04 (19.0)	0 (0.0)		
Growth					
Yes	27 (34.2)	36 (45.6)	16 (20.3)	0.001-	0.020
No	14 (60.9)	7 (30.4)	2 (8.7)	0.047	
Cold and Cough					
Rare	10 (71.4)	0 (0.0)	04 (28.6)	0.021-	0.039
Sometimes	22 (33.8)	39 (60.0)	04 (06.2)	0.077	
Frequent	09 (40.9)	03 (13.6)	10 (45.5)		
Leg and back pain					
Rare	05 (23.8)	02 (9.5)	14 (66.7)	0.001-	0.001
Sometimes	12 (24.5)	33 (67.3)	04 (8.2)	0.029	
Frequent	24 (75.0)	08 (25.0)	0 (0.0)		

Table 4 shows that time of sun exposure of participants, body exposure, frequency of vegetarian diet and non-vegetarian diet showed significant association with Vit.D levels, Duration of sun exposure was not significant with Vit.D levels but in children exposed to sunlight below half an hour Vit.D levels were below 20 ng/ml.

Table 4: ***Association of vitamin D levels with participant's sun exposure and diet***

Parameter	Vit D deficiency (<20 ng/ml) n (%)	Vit D insufficiency (>20<30ng/ml) n (%)	Vit D sufficiency (>30 ng/ml) n (%)	95% CI	*p*
Sun exposure					
Duration (hours)					
0.5	07 (46.7)	08 (53.3)	0 (0.0)	0.153-	0.265
1	15 (40.5)	12 (32.4)	10 (27.0)	0.318	
More than 1	19 (38.0)	23 (46.0)	08 (16.0)		
Time					
10:00-15:00	10 (58.8)	06 (35.3)	01 (5.9)	0.001-	0.001
15:00-18:00	01 (33.3)	02 (66.7)	0 (0.0)	0.029	
06:00-10:00	30 (36.6)	35 (42.7)	17 (20.7)		
Body exposure (%)					
<10	05 (23.8)	10 (47.6)	06 (28.6)	0.001-	0.021
10-20	25 (43.1)	21 (36.2)	12 (20.7)	0.47	
>20	11 (47.8)	12 (52.2)	0 (0.0)		
Food frequency					
Veg. diet					
Twice a month	08 (40.0)	08 (40.0)	04 (20.0)		
Twice a week	25 (44.6)	29 (59.8)	02 (3.6)	0.001-	0.010
Thrice a week	01 (33.3)	02 (66.7)	0 (0.0)	0.029	
Daily	07 (30.4)	4 (17.4)	12 (52.2)		
Non-Veg diet					
Twice a month	09 (50.0)	06 (33.3)	03 (16.7)	0.001-	
Twice a week	25 (44.6)	30 (53.6)	01 (01.8)	0.029	0.001
Thrice a week	0.(0.0)	01 (100.0)	0 (0.0)		
Daily	07 (25.9)	06 (22.2)	18 (17.6)		

As shown in Table 5A phosphorus levels showed a significant association with Vit.D levels. A weak positive correlation between phosphorus, calcium, and Vit.D levels and a weak negative correlation between weight and Vit.D were observed in Table 5B.

Table 5A: ***Association of vitamin D levels with participants' other blood biomarkers***

Parameter	Vit D deficiency (<20 ng/ml) n (%)	Vit D insufficiency (>20<30ng/ml) n (%)	Vit D sufficiency (>30 ng/ml) n (%)	95% CI	*p*
Parathyroid hormone					
Hypo	15 (40.5)	17 (45.9)	05 (13.5)	0.493-	
Normal	24 (38.1)	26 (41.3)	13 (20.6)	0.684	0.588
Hyper	01 (50.0)	0 (0.0)	0 (0.0)		
Calcium					
Hypo	03 (100.0)	0 (0.0)	0 (0.0)	0.102-	0.176
Normal	37 (38.1)	42 (43.3)	18 (18.6)	0.250	
Hyper	01 (50.0)	01 (50.0)	0 (0.0)		
Phosphorus				0.001-	
Normal	41 (40.2)	43 (42.2)	18 (17.6)	0.029	0.001

Table 5B: ***Correlation between Vitamin D and variables***

Variables	r	95% CI	*p*
Phosphorus (mg/dL)	0.232	0.023 to 0.400	0.019
Calcium (mg/ dL)	0.217	-0.012 to 0.388	0.028
Age (years)	-0.105	-0.308 to -0.095	0.292
Height (cm)	-0.047	-0.262 to -0.172	0.642
Weight (kg)	-0.231	-0.452 to -0.012	0.019
Sun exposure (%)	0.153	-0.034 to 0.329	0.124

Discussion

To our knowledge this study reports for the first time that the majority of 6-12 year old children living in the highlands (1800 metres above mean sea level) of Southern-Western Ghats of India are Vit.D-insufficient. It was primarily due to their SES and inadequate Vit.D-rich food consumption. Several systematic reviews indicated that VDD aggravated the onset of several illnesses[12-14]. Also, long-term Vit.D supplementation has been shown to overcome several diseases and delayed mortality[13,15,16]. Consequently, there are several public health campaigns to increase awareness of Vit.D in the community.

Despite ongoing public health programmes in India, prevalence of VDD is very high in all age groups, from neonates to adolescents, pregnant and lactating mothers[17]. However, few studies were conducted in India to assess VDD in young children[18]. Our study assessed that nearly 80% of 6-12 year old children residing in Southern-Western Ghats' highlands had insufficient Vit.D. Vit.D stimulates intestinal calcium and phosphorus absorption and thus systemic levels of Vit.D have positive associations with calcium and phosphorus[19]. Consistent with this, Vit.D levels of young children living in the highlands of Southern-Western Ghats, India, were positively associated with calcium and phosphorus. Our findings are similar to a previous study in a highland in Northern India[7] which reported more than 90% prevalence of VDD in young children.

One significant and independent risk factor for VDD is the population's SES[20]. Prevalence of VDD was higher in low SES families than in middle and high SES families, irrespective of the geographical location[20,21]. In India, it is well known that a significant portion of people living in highlands belonged to middle-lower SES. Consistent with the Northern highland study[7] VDD was higher in children of lower SES families in our study, suggesting that lower SES could have led to undernutrition. The critical component of undernutrition is deficiency of micronutrients, and it exists in all age groups and any SES. In our study VDD was more prevalent in low socioeconomic families. In this study, we found a significant correlation between Vit.D levels and SES. Furthermore, Vit.D levels were higher in children who consumed fish, eggs, milk, yogurt, and mushrooms once and twice a week than in those who consumed them once a month. Thus, although Vit.D fortified foods (including dairy products) have contributed to decreased rickets globally, VDD is still prevalent[22].

For most people, dietary consumption does not entirely provide the body's Vit.D requirements, and Vit.D level drops in winter[23]. Furthermore, as low concentration of Vit.D levels depend on dietary status and sunlight exposure, inadequacies become clearer as children grow up. This is one critical reason that seasonal variants should be identified when estimating Vit.D levels[24]. Another contributing factor is darker complexion which might be the reason for higher VDD levels. In our study, children were not using sunscreen for their skin, and of note, children with pale white skin had sufficient Vit.D levels. Higher melanin level decreases cutaneous production of vitamin D[25]. Individuals with high melanin concentrations (darkly pigmented skin, e.g., African Americans) have natural sun protection. However, they require five times longer UV exposure times to produce an equal quantity of Vit.D than those with lighter skin[26]. A study of sun-protective behaviour in the USA showed that staying in the shade or wearing long sleeves reduced Vit.D levels[27]. Likewise, it was evident in our study that % of body coverage has associations with VDD. A study in Southern India reported that serum Vit.D positively correlates with sunlight exposure[28]. Also, in both Kashmir valley[29] and Himachal Pradesh[7] study, Vit.D concentrations were significantly related to sun exposure. However, in our assessment, Vit.D level had no associations with sun exposure, and, likely, the stay-home measures to manage the coronavirus pandemic in the regions (before the survey) could have influenced the sun exposure observations. But of note, when the solar zenith angle becomes high, the stratospheric zone absorbs more UVB photons. Thus, very limited UVB photons can enter the earth's surface to produce cutaneous previtamin D_3. Therefore, the quantity of UVB radiation touching the earth surface is a role of solar zenith angle, the season of the year, time of the day, amount of ozone, aerosols, cloud, altitude, and latitude, which all affect the cutaneous synthesis of vitamin D_3[5]. For example, in cold seasons in areas of middle-high latitude, the solar advancement remains low during the short daylight period. Therefore, the solar UVB is inadequate in the highlands to produce adequate Vit.D. Thus, further studies on the sun exposure and solar zenith angle in highland habitats are warranted.

Conclusions

Majority of children of the 6-12 year age group living in the highlands of Southern-Western Ghats, India had vitamin D deficiency. Our findings indicated that lower socioeconomic status and inadequate consumption of vitamin D rich foods were the potential risk factors mediating vitamin D deficiency in children in the high altitude regions.

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