Indian Journal of Pediatrics (August 2022) 89(8):751–758
https://doi.org/10.1007/s12098-021-04007-w

ORIGINAL ARTICLE

Prevalence and Covariates of Vitamin D Deficiencies (VDD) among Adolescents in India

Suman Chakrabarty[1]

Received: 7 July 2021 / Accepted: 24 September 2021 / Published online: 27 November 2021

Abstract

Objective To estimate the overall burden of vitamin D deficiencies (VDD) among Indian adolescents aged 10–19 y and to explore some selected covariates to determine a comprehensive guide to explore the vulnerable segments its guiding factors of VDD.

Methods The study used secondary data of 11,822 adolescent children from the Community National Nutrition Survey (CNNS), undertaken in 2016–18. The data were analyzed by using STATA version 17.0. The multinomial logistic regression model was used to explore the covariates of VDD after adjusting all multicollinearity and giving analytical as well as sampling weights.

Results The results revealed that nearly one-fourth of adolescent children have VDD (23.46%, 95% CI: 22.69%–24.22%) across India. Children belonging to the Hindu caste population, children who occasionally (and not weekly), or never, consume eggs, children living in north Indian states specifically in Punjab, Haryana, and Uttarakhand, children belonging to the richest households (wealth index–wise), and children suffering from overweight and obesity were more inclined to VDD. In the final adjusted multinomial regression model, the odds of VDD were significantly higher among urban living children.

Conclusions Findings concluded that proper intervention programs targeting specific population groups and/or regions of India are essential to combat the burden of VDD for enriching India's sustainable development goal of eradicating hunger by 2030.

Keywords India · Adolescent children · Vitamin D · Richest · Overweight · Protein consumption

Introduction

Like overweight and obesity, vitamin D deficiencies (VDD) is also considered an epidemic, especially among adolescents worldwide [1, 2]. During the last two decades, many studies have been done due to the meaningful association between VDD and immune function, cardiovascular health, and cancer prevalence [3]. Vitamin D also plays a crucial role in calcium homeostasis and bone metabolism in the human body [4]. However, vitamin D deficiency is widespread globally, specifically in low- and middle-income countries like India, represented by limited data sources [5].

In India, few review articles highlighted the widespread prevalence of vitamin D deficiency in every corner, both based on community- and hospital-based studies [6, 7]. Many covariates are associated with VDD, like inadequate exposure to sunlight, air pollution, low amount of dietary vitamin D intake, obesity, urban living group, etc. [6]. Besides, studies also showed that girls were more prone to VDD compared to boys [8]. However, such studies had least represented the adolescent age group. One study conducted among adolescent children in Delhi showed that 45% of boys and 55% of girls suffered from VDD [9].

In order to attain the sustainable development goal of eradicating hunger by 2030, this comprehensive estimate of VDD is essential for scaling up the nutritional program for micronutrients deficiencies and also to help for finding out the vulnerable segments or states or regions. However, the estimate of VDD is still under-reported among the adolescent children in India by using national-level data despite a thematic report published with the help of CNNS data among adolescents [10]. This report was a comprehensive account of adolescent health with different parameters

✉ Suman Chakrabarty
sumanshabar@gmail.com

[1] Department of Anthropology, Mrinalini Datta Mahavidyapith, Birati, Kolkata, West Bengal 700051, India

ignoring to find out individual parameters with in-depth analysis by incorporating the suitable and available covariates. Therefore, this study attempted to estimate the overall burden of VDD among adolescent children aged 10–19 y by using the national representative data, and also to explore some selected covariates to determine a comprehensive guide to explore the vulnerable segments and its guiding factors of VDD.

Materials and Methods

The CNNS 2016–18 dataset was used for this study. The final study population comprised 11,822 children aged 10–19 y after clearing the missing values of the dataset, as shown in Table 1. The survey used a multistage sampling design for selecting a representative sample from households and individuals across 30 states in India. In order to get an accurate representation of different socioeconomic categories from the selected sample population, the present study used stratified sampling for getting rural sample at the primary stage; the same procedure was also followed during the NFHS-III survey [11]. More detailing of sampling a sample size was reported in the CNNS report during 2019 [12].

SRL Limited (a well-established diagnostic company in India) was solely responsible for analyzing the blood sample of the studied children across the 30 states in India. Systematic random sampling was used to get children aged 10–19 y to understand their vitamin D status. The phlebotomists collected a blood sample of 10 mL from each selected child in the morning. The collected blood samples were packed correctly and transported to the nearest assigned laboratories. The detailing of analyzing laboratory procedures for blood testing steps was furnished in the CNNS report [12]. The quality of the biomarker data was assured by CNNS standard operating procedures (SOPs) at three levels. The types of equipment related to anthropometric measures as well as blood sample measures were validated periodically.

Table 1 Steps of selecting the final sample from CNNS 2016–18 primary data

Criteria	Sample
Total surveyed children (10–19 y)	35,830
Sample considered for vitamin D test	15,248
Sample not received for vitamin D test	359
Test not performed for vitamin D	976
Invalid data	01
Quantity not sufficient for vitamin D test	844
Value less than 4.20	133
Invalid BMI data	1113
Total sample considered for the present study	**11,822**

The 2016–18 CNNS collected anthropometric data by measuring the height (cm) and weight (kg) of all sampled children in the selected households. At the time of taking weight and height measures, the measuring surface was made flat by placing a wooden square on the floor and checked by using spirit levellers. Electronic digital scales were used to measure weight, and height was measured standing up. The nutritional status of children in the survey population was calculated with the World Health Organization (WHO) Child Growth Standards 2007, based on an international sample of healthy children. Nutritional status was categorized as BMI for age below − 2 SD as undernutrition, –2 SD to + 1 SD = Normal, and above + 1 SD as overweight and obese, respectively [13].

Lastly, the standard protocol was used to get the 7 d key food items consumption for understating the dietary diversity of the studied children. All data have been collected between winter 2017 and spring 2018 [12].

This study has utilized secondary data obtained from the CNNS 2016–18 collected by the multi–stakeholders survey program. However, the preliminary survey received ethical approval from the Population Council's Institutional Review Board (IRB) in New York and the Postgraduate Institute of Medical Education and Research (PGIMER) in Chandigarh, India. However, ethical approval was not required for the present analysis as UNICEF provided the data for the secondary analysis research. The access to the use of datasets was obtained through written request to UNICEF.

The output variable of this study was the vitamin D deficiencies status among children 10–19 y measured by using Serum 25(OH)D concentration. Serum 25(OH)D concentration < 12 ng/mL (30 nmol/L) was considered as vitamin D deficiencies (VDD) among the study group [12].

Some selected information was extracted from the CNNS dataset, including sociodemographic behavioral and economic characteristics (adolescent sex and age, place of residence, region, social group, weekly consumption of milk, egg, fish, chicken, junk food, and wealth index). Anthropometric data comprised of height (cm) and weight (kg). The age was categorized as 10–14 y and 15–19 y. Region of India was categorized into six groups as (i) North (ii) Central (iii) East (iv) West (v) South (vi) Northeast. The consumption of considered food was also categorized as consumption 1–4 d, 5–7 d, and Occasional/Never. The wealth index based on household items was categorized into five different categories: poorest, poor, middle, rich, and richest for this present analysis at the national level.

Prevalence of VDD was considered if a child has Serum 25(OH)D concentration < 12 ng/mL (30 nmol/L) as stated above under the subheading "outcomes" out of total children aged 10–19 y. All categorical variables (sociodemographic, behavioral, and economic characteristics) were summarized using frequency distribution. Bivariate analysis was done by using the chi-square test to assess factors associated with VDD. Then multicollinearity between variables was estimated and adjusted in the further multinomial logistic regression model. The multinomial logistic regression model was applied to report the unadjusted and adjusted odds ratio (age group and sex-wise) and 95% confidence interval. All the statistical analyses were performed after adjustment with the analytical as well as sampling weights. The analysis was performed by STATA 17.0 version software (licensed), StataCorp LLC, USA. Graphs were drawn by using excel software. A p value < 0.05 was considered as statistical significance.

Results

The present study was based on the 11,822 selected adolescent children in pan Indian context (Table 2). Out of the total studied children, 50.54% of children were boys, and their majorities were lived in rural areas (78.04%). Out of all children, there was a higher representation in the age group of 10–14 y (57.50%) compared to 15–19 y (42.50%). Region-wise, more than 20% of the children lived in the central and eastern regions and belonged to the Hindu caste population (89.35%).

It was noted that a large percentage of studied children did not consume a sufficient amount of protein-rich food. It was estimated that 41.09% of children in the milk group, 63.25% of children in the egg group, 73.31% of children in the fish group did consume the items occasionally in a week or did not consume them. On the other hand, 9.04% of children consumed junk food 1–4 d a week. Economically, the studied children were evenly distributed across the economic group as around 20%. Finally, however, majorities of the children belonged to the normal nutritional group, but 4.98% of children suffered from overweight and obesity.

In the study, 23.46% (95% CI: 22.69%–24.22%) of the children had VDD (Table 3). However, the distribution of VDD according to the children age group in years and sex was statistically significant (p < 0.001). The prevalence of VDD was significantly higher among girls (33.48%, 95% CI: 31.39%–35.56%) in comparison to boys. On the other hand, children in the age group of 10–14 y were significantly higher percentage (24.43%, 95% CI: 22.32%–26.53%) of VDD than their higher age group counterpart.

The prevalence of VDD was significantly higher in urban compared to rural areas (32.38% vs. 20.40%, p < 0.001). Where the prevalence of VDD was highest in North region states (42.15%, 95% CI: 38.21%–46.08%) followed by West, East, and Central regions (Table 3). All these regions were more than 19% prevalence of VDD. On the contrary, VDD was comparatively low in the Northeastern and South regions. The overall distribution of VDD according to regions was significantly varied (p < 0.000). The state-wise distribution of the prevalence of VDD is shown in Fig. 1.

Table 2 Background characteristic of study population

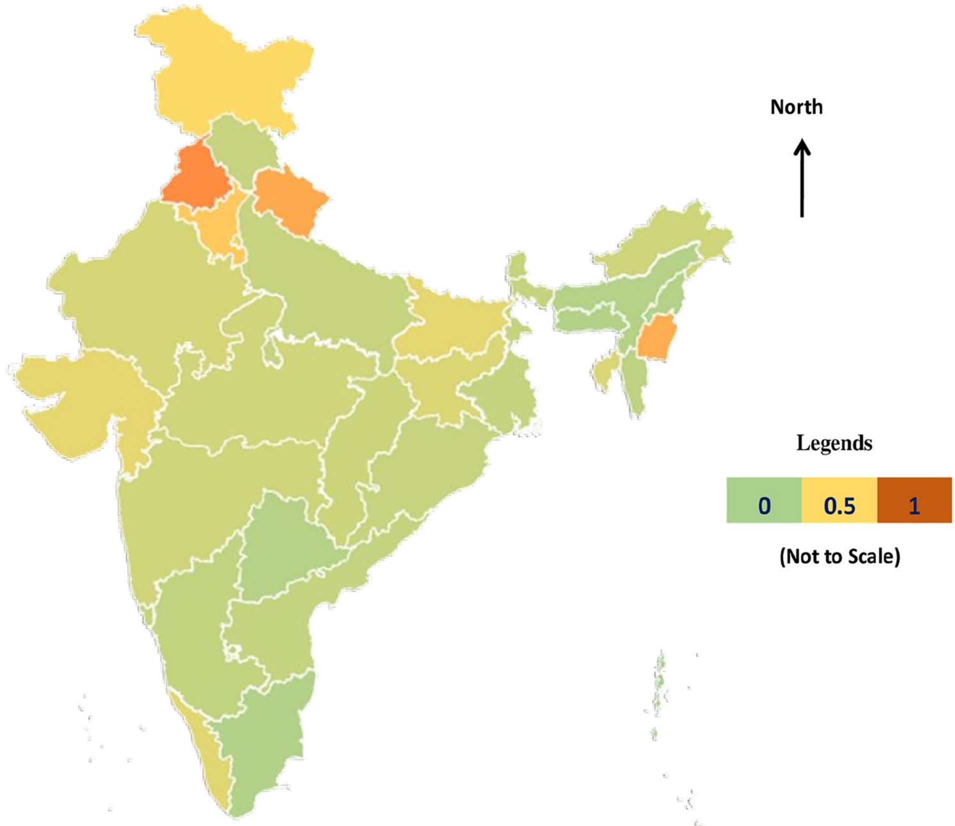
Variable	No. (n = 11,822)	%
Sex		
Boys	5975	50.54
Girls	5847	49.46
Age group of children (y)		
10–14	6798	57.50
15–19	5024	42.50
Place of residence		
Rural	9226	78.04
Urban	2596	21.96
Region		
North	1509	12.77
Central	3147	26.62
East	3504	29.64
North-east	345	2.92
West	1417	11.99
South	1901	16.08
Social group		
Caste	10,562	89.35
Tribe	913	7.73
Others	346	2.93
Consumption of milk (weekly)		
1–4 d	1376	11.64
5–7 d	5588	47.27
Occasional/Never	4857	41.09
Consumption of egg (weekly)		
1–4 d	3921	33.17
5–7 d	530	4.48
Occasional/Never	7371	62.35
Consumption of fish (weekly)		
1–4 d	2725	23.05
5–7 d	430	3.64
Occasional/Never	8666	73.31
Consumption of junk food (weekly)		
1–4 d	1069	9.04
5–7 d	159	1.34
Occasional/Never	10,595	89.62
Wealth index		
Poorest	2183	18.46
Poor	2483	21.01
Middle	2520	21.32
Rich	2485	21.02
Richest	2151	18.19
BMI group		
Undernutrition	2974	25.16
Normal	8259	69.86
Overweight/Obese	589	4.98

Table 3 Prevalence of vitamin D deficiency by background characteristics

Variable	No. ($n = 11,822$)	Vitamin D deficiency	95% CI	Chi-square test
Overall	11,822	23.46	22.69,24.22	–
Sex				
Boys	807	13.57	11.20, 15.93	652.50**
Girls	1966	33.48	31.39, 35.56	
Age group of children (y)				
10–14	1608	24.43	22.32, 26.53	7.796**
15–19	1166	22.24	19.85, 24.62	
Place of residence				
Rural	1797	20.40	18.53, 22.26	179.75**
Urban	977	32.38	29.44, 35.31	
Region				
North	605	42.15	38.21, 46.08	533.56**
Central	751	19.85	16.99, 22.70	
East	797	26.88	23.80, 29.95	
Northeast	47	11.50	2.37, 20.62	
West	349	27.89	23.18, 32.59	
South	225	11.36	7.21, 15.50	
Social group				
Caste	2567	24.11	22.34, 25.65	30.66**
Tribe	128	15.71	8.81, 21.18	
Others	78	21.93	12.72, 31.07	
Consumption of milk (weekly)				
1–4 d	320	24.04	19.32, 28.67	0.31
5–7 d	1367	23.47	20.76, 25.23	
Occasional/Never	1086	23.28	20.49, 25.50	
Consumption of egg (weekly)				
1–4 d	772	19.95	16.23, 21.76	57.28**
5–7 d	106	18.04	10.68, 25.31	
Occasional/Never	1896	25.74	23.05, 26.94	
Consumption of fish (weekly)				
1–4 d	519	19.95	15.62, 22.37	50.22**
5–7 d	51	13.39	3.76, 22.23	
Occasional/Never	2203	24.93	22.21, 25.78	
Consumption of junk food (weekly)				
1–4 d	308	28.36	22.98, 33.01	16.05**
5–7 d	40	23.62	9.95, 36.04	
Occasional/Never	2425	22.95	20.35, 23.64	
Wealth index				
Poorest	394	18.15	14.20, 21.79	217.96**
Poor	457	18.70	14.47, 21.52	
Middle	485	19.69	15.50, 22.49	
Rich	697	28.44	24.66, 31.33	
Richest	740	32.29	28.36, 35.36	
BMI group				
Undernutrition	510	17.51	13.73, 20.26	93.93**
Normal	2075	24.91	22.16, 25.83	
Overweight/Obese	188	32.55	25.33, 38.66	

*$p < 0.05$, **$p < 0.001$

Fig. 1 State-wise percentage distribution of vitamin D deficiencies among adolescents in India



It was observed that the highest prevalence of VDD was in Punjab (68.0%), followed by Uttarakhand (61.0%) and Haryana (54.0%). Exceptionally, only one state from the Northeastern region was shown a very high prevalence of VDD i.e., Manipur (60.0%).

Apart from the distribution of VDD among the studied children according to sex, age groups, region, and place of residence, the rest of the factors were also represented in Table 3. The percentages of VDD was higher among children in the Hindu caste group (24.11%, 95% CI: 22.34%–25.65%, $p < 0.000$), weekly consumption of egg as occasional and never (25.74%, 95% CI: 23.05%–26.94%, $p < 0.000$), weekly consumption of fish as occasional and never (24.93%, 95% CI: 22.21%–25.78%, $p < 0.000$), consumption of junk food 1–4 d in a week (28.36%, 95% CI: 22.98%–33.01%, $p < 0.000$), children belonging to richest wealth index group (32.29%, 95% CI: 28.36%–35.36%, $p < 0.00$), and lastly, children suffering from overweight/obesity (32.55%, 95% CI: 25.23%–38.66%, $p < 0.000$). The results are also supported by the bivariate logistic regression analysis (Table 4). The odd ratio of VDD among studied children was more likely to be 3.204 (2.709–3.790) times higher among the girls ($p < 0.000$) compared to the boys. Similarly, higher odd ratio was observed in the richest households and children who suffered from overweight and obesity.

After considering multicollinearity and adjusting the age group and sex in the multinomial logistic regression model (Table 4), it was observed that adjusted odd ratios of VDD among studied children were more likely to be significantly higher among the children live in urban areas and in contrary lower among the tribes (AOR = 0.724, 95% CI: 0.562–0.997, $p < 0.05$). Finally, even after adjustment, adjusted odd ratios of VDD among studied children were more likely to be significantly higher among the richest group (AOR = 1.752, 95% CI = 1.230–2.495, $p < 0.001$) as compared to the poorest group, and overweight/obese group of adolescent children (AOR = 2.064, 95% CI = 1.464–2.909, $p < 0.000$) as compared to undernutrition counterpart.

Discussion

The present study was aimed to understand the magnitude of VDD and its underlying covariates among adolescent children aged 10–19 y based on recent national-level representative CNNS – 2016 to 2018 survey data. After the data cleaning, 11,822 adolescent children representing 30 states and union territories in India were considered for the present study. This may probably be the first attempt to describe the findings by concentrating only on VDD among adolescent children based on CNNS data as per regions and states in

Table 4 Factor associated with vitamin D deficiencies as independent variable (multinomial logistic regression analysis)

Variable	Crude OR [95% CI]	*p* value	Adjusted OR# [95% CI]	*p* value
Sex				
Boys	1.00		–	
Girls	3.204 [2.709–3.790]	$p < 0.000$		
Age group of children (y)				
10–14	1.00		–	
15–19	0.883 [0.815–0.957]	$p < 0.001$		
Place of residence				
Rural	1.00		1.00	
Urban	1.868 [1.554–2.245]	$p < 0.000$	1.648 [1.326–2.048]	$p < 0.000$
Region				
North	1.00		1.00	
Central	0.339 [0.265–0.434]	$p < 0.000$	0.435 [0.337–0.561]	$p > 0.000$
East	0.504 [0.411–0.618]	$p < 0.000$	0.738 [0.587–0.928]	$p < 0.05$
Northeast	0.178 [0.137–0.232]	$p < 0.000$	0.254 [0.187–0.347]	$p < 0.000$
West	0.530 [0.426–0.660]	$p < 0.000$	0.539 [0.426–0.680]	$p < 0.000$
South	0.175 [0.138–0.223]	$p < 0.000$	0.181 [0.137–0.241]	$p < 0.000$
Social group				
Caste	1.00		1.00	
Tribe	0.586 [0.434–0.792]	$p < 0.05$	0.724 [0.562–0.997]	$p < 0.05$
Others	0.884 [0.581–1.345]	$p > 0.05$	1.060 [0.667–1.683]	$p > 0.05$
Consumption of milk (weekly)				
1–4 d	1.00			
5–7 d	0.968 [0.746–1.256]	$p > 0.05$	–	
Occasional/Never	0.958 [0.726–1.265]	$p > 0.05$		
Consumption of egg (weekly)				
1–4 d	1.00		1.00	
5–7 d	0.883 [0.552–1.411]	$p > 0.05$	0.934 [0.580–1.504]	$p > 0.05$
Occasional/Never	1.390 [1.160–1.666]	$p < 0.000$	1.252 [1.021–1.536]	$p < 0.05$
Consumption of fish (weekly)				
1–4 d	1.00			
5–7 d	0.620 [0.334–1.150]	$p > 0.05$	–	
Occasional/Never	1.332 [1.076–1.648]	$p < 0.000$		
Consumption of junk food (weekly)				
1–4 d	1.00		1.00	
5–7 d	0.780 [0.423–1.434]	$p > 0.05$	0.819 [0.454–1.478]	$p > 0.05$
Occasional/Never	0.752 [0.587–0.962]	$p < 0.05$	1.015 [0.771–1.337]	$p > 0.05$
Wealth index				
Poorest	1.00		1.00	
Poor	1.037 [0.731–1.471]	$p > 0.05$	1.091 [0.7671–1.552]	$p > 0.05$
Middle	1.106 [0.797–1.533]	$p > 0.05$	1.128 [0.806–1.580]	$p > 0.05$
Rich	1.792 [1.301–2.469]	$p < 0.000$	1.714 [1.214–2.420]	$p < 0.001$
Richest	2.151 [1.576–2.934]	$p < 0.000$	1.752 [1.230–2.495]	$p < 0.001$
BMI group				
Undernutrition	1.00		1.00	
Normal	1.562 [1.292–1.889]	$p < 0.000$	1.539 [1.263–1.876]	$p < 0.000$
Overweight/Obese	2.272 [1.674–3.085]	$p < 0.000$	2.064 [1.464–2.909]	$p < 0.000$

OR Odd ratio

#Sex and age group adjusted

India and also tried to find the different magnitudes over some specific covariates.

The present study finds that one-fourth of the studied adolescent children suffered from VDD (23.46%, 95% CI: 22.69%–24.22%)), which was much higher than the Sri Lankan national representative adolescent sample as 13.2% (95% CI: 11.9%–14.5%) [8] but much lower than the adolescent children from Bangladesh aged 12–16 y (46.75%) [14]. The magnitude of VDD among Indian communities based on community-based field studies in the last decade showed a prevalence ranging from 50 to 94% [6]. However, the representation of adolescent children in those studies was the least. Ritu and Gupta published a review article on VDD in India showed out of 41 articles, only six articles published with the representation of adolescent VDD problem on a regional basis [7]. However, the present study furnished quite an alarming situation of VDD among adolescent children in the Indian context, and it is equally challenging to end global malnutrition by 2030 [15].

This study revealed that children who live in the northern region were more prone to VDD. This region comprised seven states and union territories, including the highest prevalence states as Punjab, Haryana, and Uttarakhand in India. A regional study in India's northwest Punjab state also showed a very high prevalence of VDD (90%), specifically among the women and urban living group [16].

In the present study, a significant gender difference was not found in VDD prevalence, where adolescent girls were more prone to VDD than boys. VDD was higher among urban children compared to rural counterparts. The tribal children were less inclined to VDD as compared to Hindu children. This may be due to the high exposure of sunlight in rural and tribal areas compared to the urban living group [17]. The VDD was higher among those children who consume less amount of animal protein in a week. VDD was higher among the richest household children compared to poorer counterparts, and children with overweight and obesity. Similarly, a significantly high prevalence of VDD was reported in Sri Lankan obese children [18]. Other findings were also noted with different national-based and regional studies in India and abroad [6–8].

Though the present study sample is the national representative, it has several limitations, like CNNS was a cross-sectional survey. Therefore, it was hard to conclude the study outcomes using any causal relationship between VDD and its selected covariates. This study has not considered sunlight exposure and air pollution data due to a lack of data sources. Besides, this data may have some seasonal variation if it is compared to other national-based data.

Conclusion

This study suggests that 1 out of 4 adolescent children aged 10–19 y are at risk of VDD in India. The prevalence was higher among the children who lived in the Northern region and states like Punjab, Uttarakhand, and Haryana; children who lived in urban areas and those from affluent economic positions but consume less protein-rich food and suffered from overweight and obesity. Findings recommend that proper intervention programs targeting specific population groups and/or regions of India are essential to combat the burden of VDD for enriching India's sustainable development goal of eradicating hunger by 2030. Further community-based national-level studies in India are required on the temporal change between VDD and its associated factors.

Acknowledgements The author is thankful to the Ministry of Health and Family Welfare (MoHFW), Government of India, UNICEF, and Population Council for providing him the data for comprehensive VDD and anthropometric analysis. He is especially grateful to Dr. Arjan de Wagt, Chief, Nutrition Section, UNICEF, India, and Mr. Robert Johnston, Nutritional Specialist at UNICEF, for their kind cooperation in providing the raw CNNS data. Besides, the author is thankful to all the partners relating to the conduct of CNNS survey, namely Aditya and Megha Mittal for financial support, AIIMS, New Delhi, CDSA, CDC, ICMR, NIN, and others, for their technical support.

Funding Aditya and Megha Mittal financially supported the CNNS survey 2016–18. However, the funding is not related to the present research work.

Declarations

Conflict of Interest None.

References

1. Peterson CA, Belenchia AM. Vitamin D deficiency & childhood obesity: a tale of two epidemics. Mo Med. 2014;111:49–53.
2. Fiamenghi VI, Mello ED. Vitamin D deficiency in children and adolescents with obesity: a meta-analysis. J Pediatr. 2021;97:273–9.
3. Holick MF. Vitamin D: a millenium perspective. J Cell Biochem. 2003;88:296–307.
4. Wimalawansa SJ. Vitamin D: what clinicians need to know. SJDEM. 2012;2:73–88.
5. Roth DE, Abrams SA, Aloia J, et al. Global prevalence and disease burden of vitamin D deficiency: a roadmap for action in low- and middle-income countries. Ann N Y Acad Sci. 2018;1430:44–79.
6. Aparna P, Muthathal S, Nongkynrih B, Gupta SK. Vitamin D deficiency in India. J Family Med Prim Care. 2018;7:324–30.
7. Ritu G, Gupta A. Vitamin D deficiency in India: prevalence, causalities and interventions. Nutrients. 2014;6;729–75.
8. Jayatissa R, Lekamwasam S, Ranbanda JM, Ranasingha S, Perera AG, De Silva KH.Vitamin D deficiency among children aged 10–18 years in Sri Lanka. Ceylon Med J.2019;64:146–54.

9. Garg MK, Tandon N, Marwaha RK, Menon AS, Mahalle N. The relationship between serum 25-hydroxy vitamin D, parathormone and bone mineral density in Indian population. Clin Endocrinol (Oxf). 2014;80:41–6.
10. Sethi V, Lahiri A, Bhanot A, et al. Adolescents, diets and nutrition: growing well in a changing world. The Comprehensive National Nutrition Survey, Thematic Reports. Issue 1. 2019. p. 1–4.
11. International Institute for Population Sciences (IIPS) and Macro International. National Family Health Survey (NFHS–3). 2005–06: India, Vol 1, Mumbai: IIPS, 2007. p. 11–15.
12. Ministry of Health and Family Welfare (MoHFW), Government of India, UNICEF and Population Council. Comprehensive National Nutrition Survey (CNNS) National Report. New Delhi, 2019. Available at https://nhm.gov.in/WriteReadData/l892s/1405796031571201348.pdf. Accessed on 30th May 2021.
13. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ. 2007;85:660–7.
14. Zaman S, Hawlader MDH, Biswas A, et al. High prevalence of vitamin D deficiency among Bangladeshi children: an emerging public health problem. Health. 2017;9:1680–8.
15. International Food Policy Research Institute. Global nutrition report 2016: from promise to impact: ending malnutrition by 2030. 2016. https://doi.org/10.2499/9780896295841.
16. Bachhel R, Singh NR, Sidhu JS. Prevalence of vitamin D deficiency in north–west Punjab population: a cross-sectional study. Int J App Basic Med Res. 2015;5:7–11.
17. Babu US, Calvo MS. Modern India and the Vitamin D dilemma: evidence for the need of a national food fortification program. Mol Nutr Food Res. 2010;54:1134–47.
18. Adikaram SGS, Samaranayake DBDL, Atapattu N, Kendaragama KMDLD, Senevirathne JTN, Wickramasinghe VP. Prevalence of vitamin D deficiency and its association with metabolic derangements among children with obesity. BMC Pediatr. 2019;19:186