RESEARCH PAPER

Prevalence and Correlates of Vitamin D Deficiency Among Children and Adolescents From a Nationally Representative Survey in India

GARIMA RANA,[1] RANSI ANN ABRAHAM,[1] HARSHPAL SINGH SACHDEV,[2] K MADHAVAN NAIR,[3] GEETA TRILOK KUMAR,[4] PRAWEEN KUMAR AGARWAL,[5] ROBERT JOHNSTON,[6] ARJAN DE WAGT,[6] AVINA SARNA,[7] RAJIB ACHARYA,[7] AKASH PORWAL,[7] NIZAMUDDIN KHAN,[7] SOWMYA RAMESH,[7] RAHUL BHARTI,[1] KALAIVANI M,[8] LAKSHMY RAMAKRISHNAN[1]

[1]*Department of Cardiac Biochemistry, All India Institute of Medical Sciences, New Delhi.*
[2]*Department of Pediatrics and Clinical Epidemiology, Sitaram Bhartia Institute of Science and Research, New Delhi.*
[3]*National Institute of Nutrition, Hyderabad, Telangana.*
[4]*Institute of Home Economics, University of Delhi, Delhi.*
[5]*IPE Global Limited, New Delhi.*
[6]*United Nations Children Funds, Delhi.*
[7]*Population Council, Delhi.*
[8]*Department of Biostatistics, All India Institute of Medical Sciences, New Delhi.*

Correspondence to: Dr Lakshmy Ramakrishnan, Department of Cardiac Biochemistry, All India Institute of Medical Sciences, New Delhi 110 029. Lakshmy_ram@yahoo.com.
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Objective: To evaluate the prevalence of vitamin D deficiency (VDD) and its correlates among apparently healthy children and adolescents. **Methods:** We carried out a secondary analysis of data of Comprehensive National Nutrition Survey 2016-18 to analyze the pre-valence and predictors of VDD among Indian children and adolescents. **Results**: The over-all prevalence of VDD in preschool children (1-4 years), school age (5-9 years) children, and adolescents (10-19 years) was 13.7%, 18.2%, and 23.9%, respectively. Age, living in urban area, and winter season were significantly associated with VDD. Vegetarian diet and high-income households were the main risk factors observed in 5-19 years age category. Female sex and less than three hour of physical activity/week were independent risk factors among adolescents. **Conclusion**: The prevalence and determinants of VDD across different age-groups are reported, and these should be interpreted and addressed to decrease the burden of VDD in India.

Keywords: *Diet, Physical activity, Predictors, Rickets.*

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Vitamin D is essential in early period of growth and its deficiency causes adverse health consequences in later life [1]. Epidemiological studies in children have reported vitamin D deficiency (VDD) prevalence ranging from 50% to 94%, suggesting a high unmet vitamin D requirement [2,3]. However, these studies have methodological limitations such as small sample size, restricted to urban areas, improper sampling techniques, and different estimation methods and diagnostic criteria [4]. The Indian guidelines for addressing the burden of VDD were also released recently [5]. Environmental factors (air pollution, cloud cover), lifestyle factors (physical activity, sunscreen application), vegetarian dietary pattern, socio-demography and ethnicity influence the vitamin D levels.

This study evaluated the prevalence of VDD and its correlates among apparently healthy children and adolescents of India, using nationally representative data from Comprehensive National Nutrition Survey (CNNS) [6].

METHODS

The CNNS, a cross-sectional survey, was conducted in 30 states of India, between 2016 and 2018 [6]. The survey design, sampling methodology, sociodemographic characteristics and ethical approvals of the CNNS are published elsewhere [6-8]. Data were collected through household interviews and standardized protocols. Almost 50% of all the children who completed anthropometry were contacted through systematic random sampling for blood collection.

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Blood sample collection procedure and biomarker analysis methods are detailed elsewhere [6]. Briefly, trained phlebotomists collected 8 mL blood from children aged 1-4 years and 10 mL from 5-19 years for estimating micronutrient concentrations, and biomarkers for non-communicable diseases (5-19 years only). Biochemical analyses were done in a commercial laboratory (SRL Labs, Mumbai, Gurugram, and Kolkata). Serum vitamin 25(OH) D was measured by the direct competitive chemiluminescent immunoassay that detects 25-OH vitamins D2 and D3 (Advia Centaur XP, Siemens). The quality control samples were estimated with each batch on all days and the inter-assay (values obtained in different runs) and intra-assay (within the same run) coefficient of variation (CV) was calculated, which ranged between <11.9% and <5.3%, respectively. Rigorous control and monitoring systems were included in the standard operating procedures for quality assurance of biomarker data [6].

Serum 25(OH) D level <12 ng/mL was considered as an indicator of VDD [9]. Body mass index (BMI) was categorized according to the WHO Child Growth Standards, 2006 for age group 0-4 years [10], and WHO Growth Reference Data for 5-19 years [11]. Vegetarian diet was defined as consumption of plant-based food items and abstinence from meat, game, poultry, egg and fish in food intake. Sports activity (for age group 10-19 years) was defined as engagement in sports for 45 min/day at least 3 days per week. It included one or more than one activity such as aerobics, basketball/volleyball, cricket, dancing, football, hockey, martial arts, rugby/kabbadi, running/jogging, swimming lessons, swimming for fun, and tennis/badminton/ squash/other racquet sport.

For analysis of wealth groups, we categorized households into three groups based on wealth quintile i.e., low income household group comprising poor and poorest wealth quintile, middle income household group comprising middle wealth quintile, and high-income household group comprising rich and richest wealth quintile [12]. Seasonal variation of vitamin D status was studied under three seasons i.e., summer (March-June), autumn (July-October) and winter (November-February) [13].

Statistical analysis: Participants were categorized into different sub-groups to analyze the predictors for vitamin D status. Sampling weights were used to ensure appropriate representativeness of all the estimates. Categorical variables were represented as percentages and continuous variables were represented as mean levels with 95% confidence intervals (CI). The association between categorical variables were computed by chi-square test and between continuous variables were computed by linear regression analysis. Further, unadjusted and adjusted odds ratios (aOR) with 95% CI were calculated by multivariable logistic regression analysis. Variables with *P* value <0.20 in univariate analysis were included in multivariable model [14]. All the analyses was conducted using Stata 15.0 (Stata Corp LLC). *P* value <0.05 (two sided) was considered statistically significant for all the tests.

RESULTS

The flow chart detailing the samples analyzed is given in **Fig. 1**. The prevalence of VDD in the age groups 1-4 years,

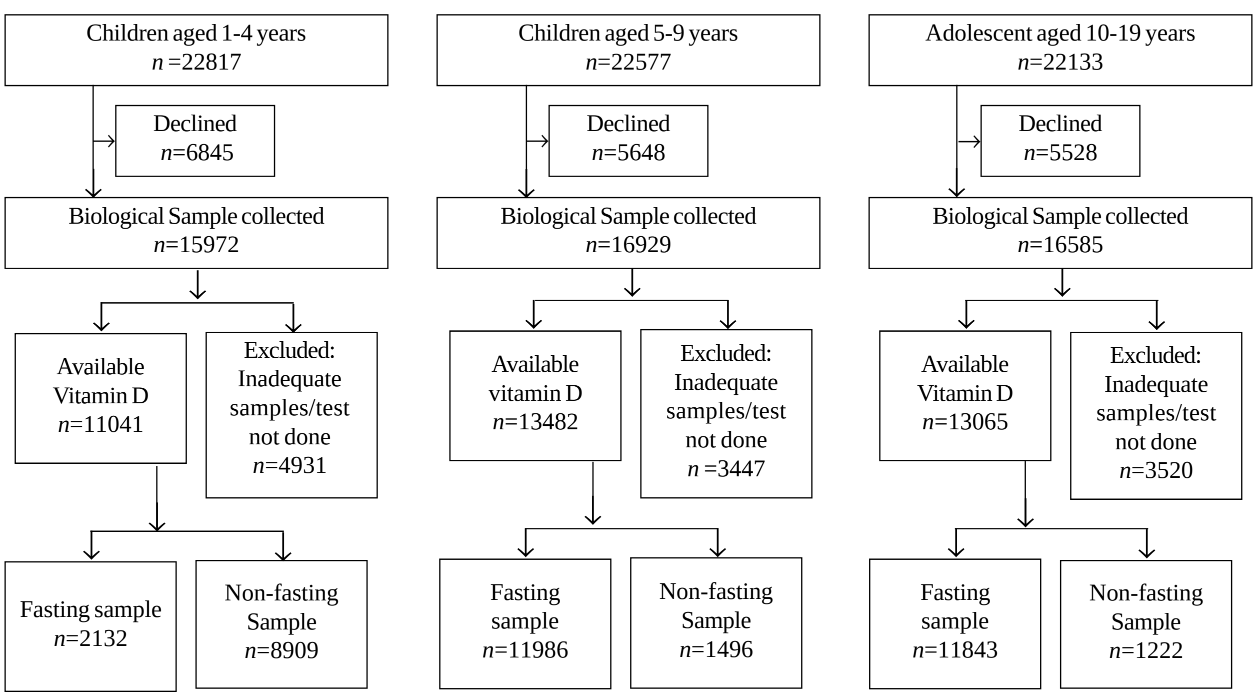


Fig. 1 Flow chart showing details of sample analysis as per different age-groups.

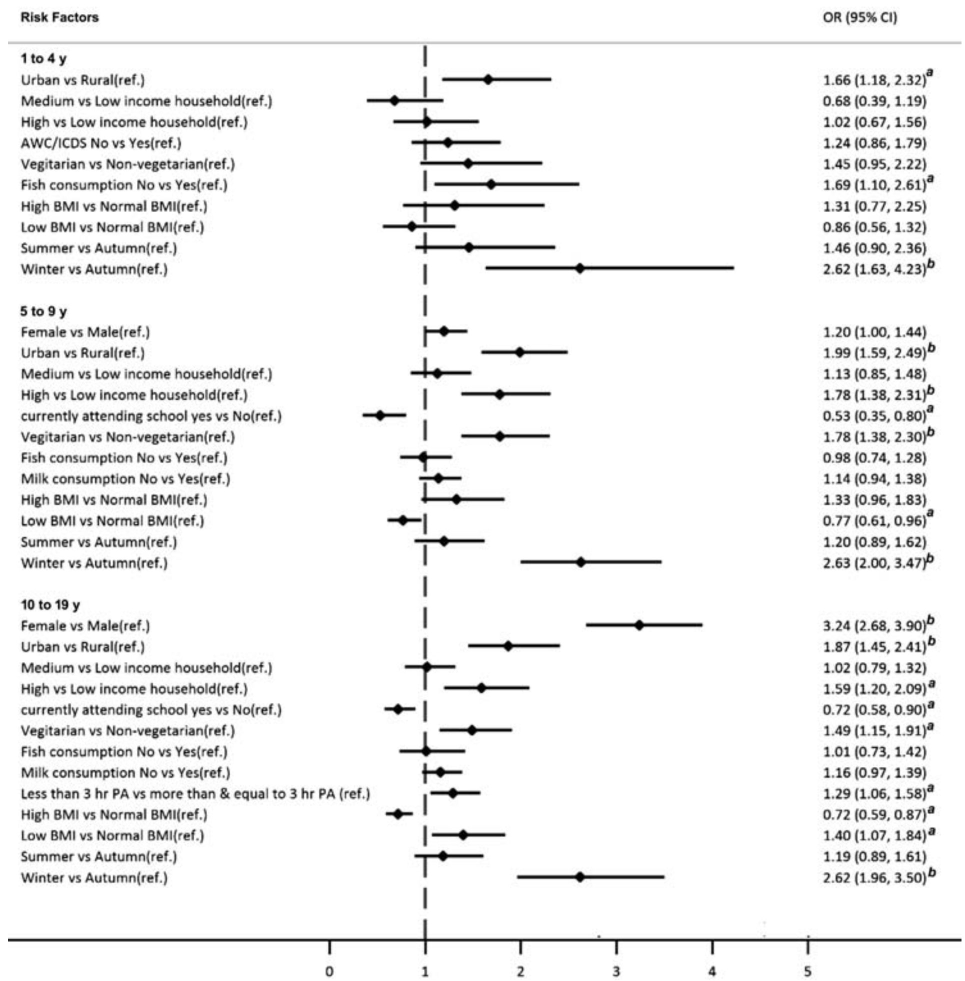
5-9 years, 10-19 years was 13.7%, 18.2% and 23.9%, respectively. Prevalence of VDD was higher in girls of age 10-19 years as compared to boys (34.3% vs 13.8%). The aOR for gender wise comparison was 1.20 in 5-9 years and 3.24 in 10-19 years. School aged children (aOR=0.6) and adolescents (aOR=0.7) who were not attending the school had lower risk for VDD than those attending the school. With respect to diet, VDD was higher among children and adolescent taking vegetarian diet than non-vegetarian diet in 1-4 years (17.5% vs 9.7%), 5-9 years (21.2% vs 14.6%) and 10-19 years (26.9% vs 20.6%) age groups, respectively. High income household (aOR=1.78 and aOR=1.59) and vegetarian diet (aOR=1.78 and aOR=1.49) were significant risk factors for VDD among children aged 5-9 year and adolescents aged 10-19 year.

The prevalence of VDD was lowest among individuals with low BMI [9.8% (aOR=0.86), 14.4% (aOR=0.77) and 17.6% (aOR=1.40)] followed by normal BMI (14.3%, 19.2% and 25.5%) and high BMI [17.2% (aOR=1.31), 27.3% (aOR=1.33) and 33.6% (aOR=0.72)] across ages 1-4, 5-9, and 10-19 years, respectively.

The association between the VDD and its correlates using multivariable regression analysis is shown in **Fig. 2**. Across all three age groups, subjects living in urban area and those who were sampled in winter season showed significantly higher odds of VDD.

DISCUSSION

The results of the present study showed a significant prevalence of VDD among the three age groups surveyed, and a disproportionate burden (1.1%-76.1%) of VDD across different states of India. Further, urban residence, non-consumption of fish, and winter season in children 1-4 years; urban residence, high income household group,



[a]*P value <0.05;* [b]*P value <0.001.*

Fig. 2 Association of vitamin D deficiency and its correlates across three age-groups. The dot shows the odds ratio and the bar shows the 95% CI.

WHAT THIS STUDY ADDS

- The age-specific and sex-specific prevalence of vitamin D deficiency from a nationally representative sample of children and adolescents aged 1–19 years in India is reported with its correlates.

attending school, high BMI, and vegetarianism among school-going children; female gender, urban residence, high income household, vegetarianism, less than three hours of physical activity/week, low BMI, and winter season among adolescents were significantly associated with increased risk of VDD. A similar Indian study using dry blood spot also reported high prevalence of VDD in children and adolescents aged 5-18 years with factors such as younger age, female gender, overweight and urban residence as risk factors [15]. Another study from Kerala also reported lower levels of vitamin D among girls than boys in children aged 5-13 years [16]. We also observed higher proportion of VDD among girls than boys in all age categories, and those residing in urban areas compared to those residing in rural areas. Similar trends of low vitamin D levels in urban population than rural have been reported earlier [17].

Higher VDD among vegetarians in the present study could be due to the limited intake of vitamin D rich products, most of which are animal source like fish and egg yolk [18]. Fortification of food with vitamin D in India is in a nascent stage, thereby making it difficult for a vege-tarian to meet the daily requirement of vitamin D.

An increased prevalence of VDD in winter season followed by summer and autumn was observed in all the age groups consistent with earlier studies [13,19]. Adolescent girls were less active physically as compared to boys in the present study. Physical activity, irrespective of indoor and outdoor in nature, was positively associated with vitamin D levels among children [20]. A reduced risk for VDD among school-aged children and adolescents who were not attending school was observed in this study, possibly linked to physical activity.

In this study, vitamin D was estimated using the chemiluminescence method rather than LC-UV or LC-MS/MS, which are the preferred methods. The factors related to sun exposure such as duration, ultraviolet B levels, air pollution levels, skin pigmentation, body coverage, sunscreen usage and vitamin D supplementation were not looked into, in the present survey. The strength of the study was that it examined the large scale population based data on vitamin D status of children and adolescents.

In conclusion, this study summarizes age- and sex-specific prevalence of VDD among children and adolescents in India. Children and adolescents should be encouraged to adopt healthy lifestyle with outdoor physical activity during sunshine and consumption of vitamin D fortified foods, specifically among girls and adolescents.

Ethics clearance: Postgraduate Institute for Medical Education and Research, Chandigarh; and the Institutional Review Board of the Population Council.
Contributors: LR, RAA, GR: conceptualized the manuscript; AS, RA, AP, SR, NK, PKA: survey data analysis; KM,GR,RB: statistical analyses for manuscript; HSS, MN, GTK, RJ, ADW, PKA: provided expert advice for the manuscript; GR: led the writing of the manuscript with inputs from LR, RAA. All authors have reviewed and approved the final version of manuscript, and are accountable for all aspects related to the study.
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Competing interests: HSS designed the draft protocol of the CNNS with consultancy support from the UNICEF, India and was member of the Technical Advisory Committee of the CNNS, constituted by the Ministry of Health and Family Welfare (MoHFW) of the Government of India (GoI), to oversee its conduct and analysis. He is a member of the World Health Organization Nutrition Guidance Expert Advisory Subgroup on Diet and Health and Guideline Development Group on 'Use and interpretation of hemoglobin concentrations for assessing anaemia status in individuals and populations', and member of the National Technical Board on Nutrition of NITI Aayog, and Expert Groups of the MoHFW; GoI on Nutrition and Child Health. GTK designed the draft protocol of the CNNS with consultancy support from the UNICEF, India and was member of the Technical Advisory Committee of the CNNS, constituted by the MoHFW, GoI, to oversee its conduct and analysis. She is also chair of a task force on Balanced and healthy diets of MoHFW, GoI, and member of other governmental expert groups and committees. MN and LR were members of the Technical Advisory Committee of the CNNS, constituted by the MoHFW, GoI, to oversee its conduct and analysis. None of the other authors listed on this manuscript report any competing interests.

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