Brief Research Article

Prevalence and Correlates of Vitamin D Deficiency among Adult Population in Urban and Rural Areas of the National Capital Region of Delhi, India

Abstract

High prevalence of Vitamin D deficiency has been reported among selective population, but its population prevalence from representative adult population is lacking in India. The aim of this study was to estimate the prevalence and identify the correlates of Vitamin D deficiency among urban and rural areas of the National Capital Region (NCR) of Delhi, India. Serum Vitamin D levels of 1403 adults (aged 30 years above), 702 from urban and 701 from rural NCR of Delhi, who participated in a representative cross-sectional survey were measured using the quantitative chemiluminescent immunoassay method. The prevalence of Vitamin D deficiency was classified as severe deficient, and insufficient at three serum levels of 25-hydroxyvitamin D–<10, 10–<20, and 20–<30 ng/mL, respectively. The median (interquartile range) 25-hydroxyvitamin D levels in urban and rural areas were 7.7 (5.2, 10.8) ng/mL and 16.2 (10.9, 22.3) ng/mL, respectively. The prevalence of Vitamin D severe deficiency, deficiency, and insufficiency in urban areas were 71%, 27%, and 2%, respectively. The corresponding prevalence in rural areas was 20%, 47%, and 25%. Urban location (odds ratio [OR] [95% confidence interval [CI]: 11.7 [8.6, 15.9]), female gender (OR [95% CI]: 1.5 [1.1, 2.2]), and abdominal obesity (OR [95% CI]:1.5 [1.1, 2.0]) were independently associated with severe deficiency. This study revealed a high prevalence of severe vitamin deficiency among the adult living in NCR, more so among urban areas, women, and obese.

Keywords: *25-hydroxyvitamin D, abdominal obesity, obesity, prevalence, risk factors, Vitamin D*

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Introduction

Vitamin D is an essential micronutrient that plays a crucial role in various systems of body, including skeletal, immune regulation, and various metabolic processes. Deficiency or insufficiency of Vitamin D has been associated with skeletal abnormalities, type 2 diabetes, chronic inflammation, metabolic syndrome, cardiovascular diseases, neurocognitive disorders, and cancers. Low serum Vitamin D levels have also been linked to higher all-cause mortality.[1] It is amenable to correction.

Despite abundant sunlight, Vitamin D deficiency is highly prevalent across different regions of the world, including India. Previous studies in Delhi and other parts of India have been limited by small sample sizes and selective groups with no population-representative data.[2] Universal screening for serum Vitamin D levels is impractical and costly. Therefore, identifying the risk factors associated with Vitamin D deficiency can be useful for implementing targeted interventions. This study aims to report the prevalence and correlates of Vitamin D deficiency in a representative sample of adults from both urban and rural populations in the National Capital Region (NCR) of Delhi, India.

Methods

This study was based on a cross-sectional survey of the rural and urban population residing in the NCR of Delhi in 2010–2012. The detailed methodology and results of the above survey are published elsewhere.[3] In brief, adults aged 30 years and above were selected with the rural sample collected from villages of the Ballabgarh Health and Demographic Surveillance System and the urban from 12 wards of Municipal Corporation of Delhi. A total of 2190 urban and 2776 rural individuals were interviewed, and biospecimen was collected for the primary survey. The blood and urine collected were processed the same day and

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were aliquoted and stored in a deep freezer (−80°C) till they were analyzed. The study received ethical clearance by the Ethics Committees of the coordinating institutions.

The sample size for further analysis was estimated to detect an odds ratio of 1.8, assuming 5% type 1 error, 80% power, and based on 50% Vitamin D deficiency exposure status in the sample. We estimated Vitamin D levels in 1403 subjects - 702 rural and 701 samples, randomly selected from the urban sample set.

Vitamin D assessment

Vitamin D was measured using the quantitative chemiluminescent immunoassay method using the DiaSorin Liaison™ 25 OH Vitamin D TOTAL Assay kit on a Liaison™ analyzer. This assay measures total 25-hydroxy Vitamin D and other hydroxylated Vitamin D metabolites in human serum.

Two levels of internal quality control (IQC) were run with each batch of samples. A QC from DiaSorin was run along with a third-party IQC purchased from RANDOX (Immunoassay tri-level QC). The low and high controls values were 4.8 and 70 ng/mL, respectively. The intra-assay coefficient of variation done on 5% of the sample was 4.3%. Repeat measurements were done on 15% of samples analyzed, i.e., 239 samples that included 83 (rural) +156 (urban) samples. For external quality assurance, the laboratory was part of the Randox International Quality Assurance Scheme, UK.

Definitions

Subjects were labeled to have diabetes mellitus according to the WHO criteria.[4] Hypertension was defined using the Joint National Committee VIII criteria.[5] National Cholesterol Education Program Adult Treatment Panel III cutoffs were used to define overweight.[6] Abdominal obesity was defined as waist-to-hip ratio >0.90 for men and >0.85 for women.[7] Physical activity levels were categorized by the definitions used in the Global Burden of Disease study.[8] Smoking was defined as the use of any smoked tobacco product such as a cigarette, bidi, hookah, chillum, or cigar in the past 6 months. Alcohol use was defined as consumption in the last 12 months of any alcohol product.

Statistical analysis

The Vitamin D deficiency was determined at three serum levels of Vitamin D–<10, 10–<20, and 20–<30 ng/mL as severe deficiency, deficiency, and insufficiency, respectively.[9] The Vitamin D levels were further stratified based on demographic information and cardiovascular risk factors to assess the relative prevalence of Vitamin D deficiency in these subpopulations. Vitamin D levels were presented as median (interquartile range [IQR]) or frequency (percentage) as appropriate. Chi-squared test was used to test the observed difference in prevalence of Vitamin D deficiency between the categories. Subsequently, multiple logistic regression models were used to estimate the independent associations between Vitamin D deficiency and demographic, behavioral and biochemical correlates (gender, locality of stay (urban/rural), current smoking, alcohol use, physical activity, body mass index, waist–hip ratio, hypertension, diabetes mellitus). A two-sided $P < 0.05$ was used to indicate statistical significance. We used STATA version 16.1 (StataCorp LLC, College Station, TX, USA), for all analyses.

Results

The mean (standard deviation) age of the urban and rural sample was 46.3 (13.0) years and 47.5 (12.9) years, respectively. The urban and rural sample selected for the current study had similar age and gender distribution to the original cross-sectional survey.

The prevalence of Vitamin D sufficiency, insufficiency, deficiency, and severe deficiency in total, urban, and rural populations is shown in Figure 1, with severe deficiency being reported among 71% and 20% in urban and rural NCR, respectively. Only 1% and 9% of individuals in urban and rural areas, respectively, had sufficient Vitamin D levels. The median (IQR) Vitamin D levels in urban and rural areas were 7.7 (5.2, 10.8) ng/mL and 16.2 (10.9, 22.3) ng/mL, respectively.

The levels of Vitamin D stratified by demographics and risk profile of individuals in urban and rural NCR are shown in Tables 1 and 2. Women had lower levels of Vitamin D levels in both urban and rural areas. However, vitamin deficiency was highly prevalent among all the age groups. We found no association between Vitamin D levels and factors such as tobacco use, physical activity, diabetes, and hypertension in both urban and rural areas. While we observed a significant positive association in the univariate analysis between generalized obesity and Vitamin D deficiency, it disappeared after adjusting for other variables. Further, there was a negative association between Vitamin D deficiency and alcohol use among the urban population. In multivariable logistic regression analysis, urban

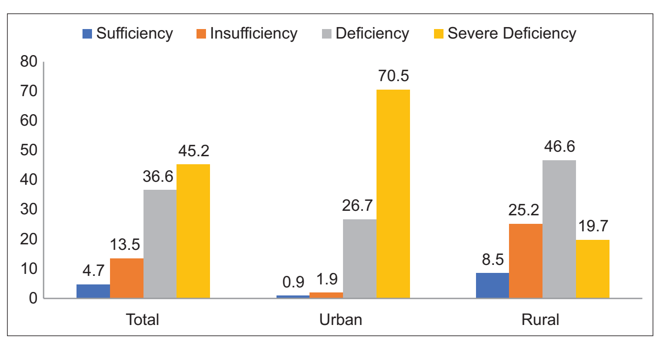

Figure 1: Prevalence of Vitamin D sufficiency (≥30 ng/mL), insufficiency (20–<30 ng/mL), deficiency (10–20 ng/mL), and severe deficiency (<10 ng/mL) among residents of National Capital Region of Delhi, India

Table 1: Vitamin D status by different demographic, socioeconomic, and cardiovascular risk factors in rural population

Variable	Category	Participants (*n*)	Median (IQR)	Prevalence of Vitamin D Insufficiency (20–<30 ng/mL)	Prevalence of Vitamin D deficiency (10–<20 ng/mL)	Prevalence of severe Vitamin D deficiency (<10 ng/mL)	*P*
Age (years)	30–45	383 (53.4)	16.6 (11.1–22.3)	97 (26.0)	171 (45.8)	73 (19.6)	0.6
	46–60	201 (28.0)	15.7 (10.9–21.8)	42 (21.2)	102 (51.5)	37 (18.7)	
	>60	133 (18.6)	16.5 (10.5–23.4)	38 (29.0)	54 (41.2)	28 (21.3)	
Gender	Male	323 (45.1)	17.5 (11.8–23.4)	91 (29.1)	130 (41.5)	57 (18.2)	0.009
	Female	394 (55.0)	15.6 (10.8–20.9)	86 (22.1)	197 (50.6)	81 (20.8)	
Education	Primary to high school	302 (80.3)	16.2 (10.8–23.6)	64 (21.7)	135 (45.8)	58 (19.7)	0.181
	Secondary/graduate	74 (19.7)	17.8 (12.7–22.3)	23 (31.5)	34 (46.6)	11 (15.1)	
Tobacco use	Yes	286 (39.9)	15.9 (10.5–22.1)	77 (27.7)	122 (43.9)	58 (20.9)	0.438
	No	431 (60.1)	16.4 (11.2–22.4)	100 (23.6)	205 (48.3)	80 (18.9)	
Alcohol use	Yes	207 (28.9)	17.4 (11.7–23.0)	61 (30.2)	83 (41.1)	39 (19.3)	0.18
	No	510 (71.3)	15.9 (10.8–21.9)	116 (23.2)	244 (48.8)	99 (19.8)	
BMI (kg/m2)	<20	187 (26.1)	16.4 (10.8–22.1)	51 (27.4)	80 (43)	39 (21)	0.987
	20–25	299 (41.7)	16.1 (11.1–23.0)	71 (24.5)	138 (47.6)	54 (18.6)	
	>25–30	169 (23.6)	16.4 (11.0–21.7)	40 (24.2)	81 (49.1)	32 (19.4)	
	>30	62 (8.7)	16.1 (10.8–21.7)	15 (24.6)	28 (45.9)	13 (21.3)	
Abdominal obesity (WHR)	Yes	506 (70.7)	15.9 (10.8–21.8)	125 (25.2)	235 (47.4)	102 (20.6)	0.082
	No	210 (29.3)	17.1 (11.8–23.6)	52 (25.4)	91 (44.4)	36 (17.6)	
Hypertension	Yes	185 (25.8)	16.6 (11.0–22.9)	63 (30.9)	91 (44.6)	39 (19.1)	0.063
	No	532 (74.2)	15.9 (10.9–21.8)	114 (22.9)	236 (47.4)	99 (19.9)	
Diabetes mellitus	Yes	79 (11.2)	18.5 (11.5–23.0)	6 (42.9)	5 (35.7)	2 (14.3)	0.5
	No	629 (88.8)	16.2 (10.9–22.3)	171 (24.9)	322 (46.8)	136 (19.8)	

BMI: Body mass index, WHR: Waist–hip ratio, IQR: Interquartile range

location, (11.7, 8.6–15.9), female gender (1.5, 1.1–2.2), and abdominal obesity (1.5, 1.1–2.0) were independently associated with severe Vitamin D deficiency [Table 3].

Discussion

This study from India reports Vitamin D levels in a representative adult population group from the rural and urban populations. We found a very high prevalence of Vitamin D deficiency in the population, more marked among urban residents, women, and centrally obese individuals.

A high prevalence of Vitamin D deficiency has previously been reported in all regions of the country among healthy children, adolescents, young adults, and those ≥50 years old.[10-14] Most of these Indian studies were conducted among the urban population. The reported prevalence of Vitamin D deficiency among the adult population ranged from 50% to 94%. The burden of Vitamin D deficiency reported by our study is higher than a similar population-based study from South Asia.[15]

The prevalence of severe Vitamin D deficiency in our study was more than 3 times higher among both urban men and women population as compared to their rural counterparts. A similar community-based study from South India also reported a significant urban and rural divide among men but equal and high burden among women. In that study, 44% of the men and 70% of women from the rural areas had Vitamin D levels of <20 ng/mL. While in the urban area, the prevalence among men and women was 62% and 75%, respectively.[16] The urban propensity for Vitamin D deficiency may be related to increased indoor lifestyle and reduced sunlight exposure, changing food habits that contribute to low dietary calcium and Vitamin D intake. Severe air pollution that blocks sunlight in urban Delhi may also contribute to the reduced Vitamin D levels.

Gender-wise comparison in our study reveals that women are more affected with Vitamin D deficiency than men, irrespective of their location of residence and presence of comorbid conditions. This is consistent with a recent systematic review and meta-analysis from South Asia, which reported that 76% of women (95% confidence interval [CI]: 68%–82%) opposed to 51% of men (95% CI: 33%–71%) had Vitamin D deficiency.[15] The increased prevalence of Vitamin D deficiency among women might be related to cultural reasons. Indian women spend more time indoors than their male counterpart which effectively limits their exposure to direct sunlight. The traditional cloths practiced across women in religious groups in India to block direct sunlight exposure.

The current study did not report any difference in Vitamin D levels among smokers and nonsmokers. While many published studies have shown the effect of smoking on Vitamin D, others have shown that there is no statistically significant effect on circulating Vitamin D levels.[17] However, low levels of Vitamin D among smokers in the

Table 2: Vitamin D status by different demographic, socioeconomic, and cardiovascular risk factors in urban population

Variable	Category	Participants (*n*)	Median (IQR)	Prevalence of Vitamin D insufficiency (20–<30 ng/mL)	Prevalence of Vitamin D deficiency (10–<20 ng/mL)	Prevalence of severe Vitamin D deficiency (<10 ng/mL)	*P*
Age (years)	30–45	397 (56.4)	7.7 (5.1–10.6)	11 (2.8)	97 (24.6)	285 (72.1)	0.8
	46–60	187 (26.6)	7.8 (5.2–11.3)	1 (0.5)	56 (30.0)	126 (67.4)	
	>60	120 (17.1)	7.8 (5.4–10.8)	1 (0.8)	34 (28.6)	84 (70.6)	
Gender	Male	311 (44.2)	8.4 (5.8–11.9)	9 (2.9)	106 (34.2)	195 (62.9)	<0.001
	Female	393 (55.8)	7.0 (4.8–9.7)	4 (1.0)	81 (20.7)	300 (76.7)	
Education	Primary to high school	216 (45.6)	7.7 (5.1–10.6)	2 (0.9)	56 (25.9)	156 (72.2)	0.291
	Secondary/graduate	258 (54.4)	8.1 (5.7–11.3)	9 (3.5)	70 (27.3)	175 (68.4)	
Tobacco use	Yes	97 (13.8)	6.9 (4.3–11.1)	4 (4.1)	27 (27.8)	66 (68.0)	0.236
	No	607 (86.2)	7.8 (5.3–10.8)	9 (1.5)	160 (26.5)	429 (71.0)	
Alcohol use	Yes	155 (22.0)	8.4 (6.0–12.2)	4 (2.6)	60 (39)	90 (58.4)	0.001
	No	549 (78.0)	7.5 (5.0–10.2)	9 (1.6)	127 (23.2)	405 (74.0)	
BMI (kg/m^2)	<20	187 (26.1)	7.1 (5.1–10.6)	2 (2.3)	20 (23.3)	63 (73.3)	0.276
	20–25	299 (41.7)	8.0 (5.0–11.6)	7 (2.8)	76 (30.6)	164 (66.1)	
	>25–30	169 (23.6)	7.9 (5.5–10.4)	3 (1.2)	63 (24.6)	186 (72.7)	
	>30	62 (8.7)	6.8 (4.7–9.9)	0	26 (24.5)	80 (75.5)	
Abdominal obesity (WHR)	Yes	506 (70.7)	7.4 (5.1–10.5)	9 (1.8)	125 (25.2)	359 (72.2)	0.539
	No	210 (29.3)	8.2 (5.6–11.2)	4 (2)	61 (30.3)	134 (66.7)	
Hypertension	Yes	185 (25.8)	7.7 (5.0–10.9)	5 (1.8)	77 (27.3)	197 (69.9)	0.948
	No	532 (74.2)	7.7 (5.3–10.7)	8 (1.9)	110 (26.3)	298 (71.1)	
Diabetes mellitus	Yes	79 (11.2)	8.5 (5.4–11.9)	1 (1.1)	31 (33)	61 (64.9)	0.468
	No	629 (88.8)	7.5 (5.1–10.6)	12 (2)	156 (25.7)	434 (71.5)	

BMI: Body mass index, WHR: Waist–hip ratio, IQR: Interquartile range

current study have public health implications as it has the potential to exacerbate the risk of tobacco related cancers.[18]

The observed relationship between alcohol use and Vitamin D levels among urban residents should be interpreted with caution. A recent systematic review reported heterogeneous results with a similar number of articles indicating a positive association, a negative association, or the absence of any association between alcohol use and Vitamin D levels.[19]

Our study revealed a significant association between abdominal obesity and severe Vitamin D deficiency among Indians. We have previously reported that in 20 years, the burden of abdominal obesity in the Delhi NCR has increased by more than 70% in both urban and rural areas.[3] Abdominal obesity and associated chronic inflammation are major risk factors for insulin resistance, type 2 diabetes, and cardiovascular diseases. Several studies have reported a negative association between abdominal obesity and serum Vitamin D levels.[20] However, the direction of association is yet to be established. In our analysis, we used severe Vitamin D deficiency as the outcome of interest and abdominal obesity as the exposure variable. A recent systematic review and meta-analysis, performed with a similar hypothesis, concluded that abdominal obesity based on waist circumference was associated with increased risk of combined Vitamin D deficiency and insufficiency.[20]

Several pathophysiologic mechanisms have been postulated to explain the relationship between abdominal adiposity and Vitamin D. Vitamin D requirements among obese individuals must be more compared to others as they have weaker bones. People with abdominal obesity tend to have low level of physical activity and inadequate sun exposure. In the current study, 67% of the individuals with abdominal obesity were either inactive or with a low level of physical activity. In obese individuals, there is greater tendency to store Vitamin D in their abdominal adipose tissue and the circulating Vitamin D levels is thus reduced.

Strengths and limitations

To the best of our knowledge, this is one of the largest studies with robust methodology from north India comparing the urban and rural Vitamin D prevalence in a representative adult population. The correlates were collected as part of an earlier survey and were independent of the current study and thus not subject to a bias. Nonetheless, our study had limitations: we didn't account for factors like sunlight exposure, season, vitamin D intake, serum calcium, and phosphate concentration, which can influence vitamin D levels, as the information wasn't available. Moreover, we only focused on adults above 30, so we couldn't assess vitamin D deficiency in younger individuals.

Conclusions

The study reveals alarmingly high levels of severe Vitamin deficiency in Delhi-NCR, more in the urban areas, women, and those with abdominal obesity. The strategies of Vitamin D deficiency prevention have generally relied on Vitamin D

Table 3: Factors associated with severe Vitamin D deficiency

Variables	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Gender		
Male	Reference	Reference
Female	1.4 (1.1–1.7)	1.5 (1.1–2.2)
Location		
Rural	Reference	
Urban	9.8 (7.7–12.6)	11.7 (8.6–15.9)
Tobacco use		
No	Reference	Reference
Yes	0.5 (0.4–0.6)	1.4 (0.9–1.9)
Alcohol use		
No	Reference	Reference
Yes	0.6 (0.5–0.8)	0.8 (0.5–1.2)
Physical activity		
Inactive to low	Reference	Reference
Moderate	1.02 (0.8–1.3)	0.8 (0.6–1.1)
Highly active	0.7 (0.5–1.01)	0.6 (0.4–1.0)
Obesity (kg/m^2)		
BMI <30	Reference	Reference
BMI ≥30	1.6 (1.2–2.2)	1.2 (0.8–1.8)
Abdominal obesity (WHR >0.90 cm for men and >0.85 cm for women)		
No	Reference	Reference
Yes (WHR >0.90 cm for men and >0.85 cm for women)	1.2 (0.9–1.5)	1.5 (1.1–2.0)
Diabetes mellitus		
No	Reference	Reference
Yes	1.3 (0.9–1.7)	0.8 (0.6–1.2)
Hypertension		
No	Reference	Reference
Yes	1.1 (0.9–1.4)	0.9 (0.7–1.2)

OR: Odds ratio, CI: Confidence interval, BMI: Body mass index, WHR: Waist–hip ratio

supplementation, especially to risk groups. Given its high prevalence, appropriate public health interventions should be considered for its prevention and management.

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Conflicts of interest

There are no conflicts of interest.

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