Original Article

Prevalence of vitamin D deficiency/Insufficiency and its metabolic associations in an urban setting in Sri Lanka: Data from Colombo Urban study

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Abstract

Introduction:

Vitamin D deficiency is a commonly prevalent, but less attended problem in Asia. Vit D status has many metabolic associations. We designed this community-based study to describe the prevalence of vitamin D deficiency/insufficiency and its metabolic associations in Sri Lankan population.

Methods:

A representative sample aged 18 years and above was included. Demographic, anthropometric, and social details were recorded using a standard proforma. Blood analysis was done for vitamin D status, and other metabolic parameters. Prevalence was estimated using weighted age standardized calculations. Multiple logistic regression analyses were used to study associations to vitamin D status.

Results:

Cumulative community prevalence of Vit D deficiency and insufficiency was 90.2%. Prevalence was highest among young and females. Obese had significantly lower vitamin D levels. According to the linear regression, Moors showed a significantly lower Vit D levels compared to Sinhalese while Triglyceride levels showed an inverse association with Vit D levels. Dysglycaemia was not associated with Vit D deficiency.

Discussion:

Very high prevalence of Vit D problem was anticipated on clinical grounds and this is comparable with regional data. High prevalence among young needs early attention to avoid future poor bone health outcomes. Moor ethnicity shows high rates due to many known factors. Obesity is an emerging health problem in the country and co existent Vit D deficiency would increase its burden.

Conclusion:

Vitamin D deficiency and insufficiency and other metabolic problems are highly prevalent in this population. Causative factors and consequences of this problem should be further researched to plan strategies to replete the Vit D and prevent this problem.

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Introduction

Vitamin D deficiency is pandemic and widespread across the world irrespective of age, gender, race and geography, yet it is one of the most under-diagnosed and under-treated nutritional deficiency. Cut off values for vitamin D deficiency has been debated long, but lately, the Institute of Medicine (IOM) has defined Vitamin D deficiency as a 25(OH)D of less than 20 ng/ml and Vitamin D insufficiency as a 25(OH)D of 21–29 ng/ml (1,2).

Vitamin D is unique among hormones because it can be photosynthesized in skin on exposure to Ultraviolet B rays, and thus adequate sun exposure alone ought to suffice for vitamin D sufficiency. However, studies from South Asia over last decade have shown that hypovitaminosis D is highly prevalent (70-100%) across the region despite plentiful sunshine in the area (1-5). Natural dark skin and diversified socio-cultural, religious and economic factors of the region thought to be contributed to this problem. People with a dark skin tone have natural sun protection and require at least three to five times longer exposure to make the same amount of vitamin D as a person with a white skin tone (6,7). Rapid unplanned urbanization in the South Asian region associated with air pollution and lack of outdoor activities has further compounded this problem (1).

Sri Lankan data on vitamin D status is limited, but according to two community based studies, prevalence of vitamin D deficiency (defined as 25(OH)D less than 25nmol/l) was 6.5% among community dwelling Ethnic Tamil women from central hills and 40.5% in a cohort of women from Southern coastal area (8,9). Despite absence of strong data, very high prevalence of vitamin D deficiency/insufficiency is anticipated due to increased numbers of individuals with this problem encountered daily in the Sri Lankan clinical setting.

Many cross sectional, observational studies have identified several important metabolic associations of vitamin D deficiency, even though their cause-effect relationship is not yet well established. Association between obesity and vitamin D deficiency is well known, although the exact explanation for this is unknown. It has been postulated that obese individuals may avoid sun exposure and consume micronutrient deficient diet. Alternatively, their production of active vitamin D metabolites is enhanced, which in turn exerts negative feedback on vitamin D synthesis in liver. In addition, it is suggested that the metabolic clearance of vitamin D may increase in obesity, possibly with enhanced uptake by adipose tissue (10-12).

Several meta-analyses of observational studies have showed inverse relation of 25(OH)D levels with insulin resistance, hyperglycemia metabolic syndrome and cardiovascular morbidity. Evidence has shown that, Vitamin D receptors are present in pancreatic beta cells and peripheral target organs (skeletal muscles), and thus play a important role in regulating insulin secretion, as well insulin sensitivity. However, interventional studies and randomized clinical trials have shown conflicting results on the effects of vitamin D repletion on dysglycaemia and metabolic profile (13-16).

Therefore, we designed this community based cross-sectional study in an urban setting in Sri Lanka to describe the community-based prevalence of vitamin D deficiency and insufficiency in this population. We further analyzed our data to revisit the known metabolic associations to the vitamin D status in our population.

Methodology

Subjects and Sampling:

A community based descriptive cross-sectional study was carried out in the Eastern Kuppiyawaththa local government (Grama-Niladhari) division of the Colombo District, which was selected as it is the closest to the main research center, National Hospital of Sri Lanka during 2014/2015. This Vitamin D prevalence study was carried out as a major component of Colombo urban study.

Sample size was calculated using the Lwanga and Lameshow 1991 formula of n = z2 p (100-p)D/ d2. Expected prevalence of vitamin D deficiency and insufficiency/ dysglycaemia and obesity were taken as 50% and with design effect of 1.2%, precision of 95% and an anticipated 25% non-response, sample size was calculated as 600 using the EPI 6 sample calculation software.

A sample of 463 aged 18 years and above from the total population of 6473 in the GN area in three strata of the age categories was selected using stratified simple random sampling. The sample was divided among the 3 age categories of 18-40 years, 40-60 years and above 60 years on a weighted basis that took into account the proportion in the population and the expected prevalence of metabolic derangement / vitamin D deficiency, insufficiency in order to ensure the precision of the estimates in the sub sample analysis. Using a random number generator, study subjects were randomly

selected into the three age strata. The resulting disproportionate sample allocation was accounted for, by the use of weighted analysis. The weights were the inversion of the sampling fractions in the analysis.

Data Collection:

The participants were recruited at their homes by a team of researchers after providing an invitation letter and information documents. On the day of the screening, informed written consent was taken and data including socio-demographic data, use of alcohol, smoking, and detailed medical history on previous diagnoses and treatment were collected using interviewer-administered questionnaire by trained interviewers. Anthropometric measurements were made (weight, height, waist circumference, total body fat estimation and visceral fat percentage using a bio impedance analyzer-OMRON HBF 516). The following were measured in nine to twelve hours fasting stage: Plasma Glucose (GOD- PAP5 method, Olympus AU 480/680/400 analyser), Cholesterol (CHOD-PAP method, Olympus AU 480/680/400 analyser), Triglyceride (GPO-PAP method, Olympus AU 480/680/400 analyser), glycosylated hemoglobin (HPLC method, Bio-Rad Variant II Turbo analyser), Corrected Calcium (Arzenso III method, Olympus AU 480/680/400 analyser), and 25-OH Vitamin D level (Direct Chemiluminescence method, Advia centaur analyser). Vitamin D deficiency and insufficiency was defined according to IOM cut off values as less than 20ng/ml for deficiency and 20-30ng/ml for insufficiency (2).

Statistical Analysis:

Data analysis was performed in the R programming language version 3.2.2 (17). Community based prevalence with 95% confidence intervals for the urban study population and for different strata including age and gender were calculated considering the stratified sampling methodology using the "Survey" package in the R programming language. Descriptive data analysis was done and tabulated to present study population characteristics and prevalence of vitamin D deficiency/insufficiency.

Exploratory data analysis was done to identify the variables associated with vitamin D levels. The variables studied were age, gender, ethnicity, education level, smoking habits, alcohol consuming habits, diabetes and prediabetes, hyperlipidaemia, total cholesterol, low-density lipoprotein cholesterol (LDL), high-density lipoprotein cholesterol (HDL) and triglycerides (TG). Initially, each study variable was screened with simple linear regression, and the variables significant at P =0.2 level were subsequently used for multiple variable analysis with multiple linear regression. Significant variables at multiple variable analysis were selected for the final model. The study variable Ethnicity had 4 categories (i.e. Sinhalese, Tamils, Moors and Other) where the "other" ethnicity had only 4 individuals and this group was not considered in reporting prevalence rates and analyzing interaction at the final model. P value of 0.05 were considered as significant.

Ethical approval:

Ethical approval was obtained from the Ethical Review committee of the Faculty of Medicine, University of Colombo. No invasive procedures used for this study and there was no anticipated risk to the participants. Documents were encoded to avoid any identifying character and measurements taken to ensure confidentiality of personal information.

Results

Basic demographic and Metabolic characteristics of the study population:

A total of 463 subjects completed the study and majority of participants were females (69%) across all age strata. There were 124 (70% females), 209 (73% females) and 130 (63% females) participants in the 18-40 years, 41-60 years and over 60-year age strata consecutively. The response rate in each of the above age strata was 59%, 87%, and 87% with an overall response rate of 77.2%. Current or ex-smokers accounted for 14.4% of total, while 20.1% were current or ex- alcohol consumers.

This population had a mean body Mass Index of 25.1 kg/m2 (SD 4.8), and 68.2% of the women and 59.1% of the men were overweight or obese based on South Asian criteria (18,19) Community prevalence for abdominal obesity was 58.1% based on International Diabetes Federation cut-off values on waist circumference for determining abdominal obesity in South Asians (WC – male >= 90cm, female >=80cm) (20). Mean total body fat percentage estimated with bio impedance analysis was 34.5 % (SD 10.5) and the estimated visceral fat was 9.5 % (SD 8.2). Estimated prevalence of Diabetes Mellitus was 27.6% (95% CI 23.7-31.4) and the age adjusted community prevalence was 27.1% based on the ADA/WHO criteria.

Prevalence of Vitamin D deficiency/ Insufficiency:

Median (Interquartile range) 25(OH) D level of the study population was 18.9 (15.3 – 24.6) ng/ml (Figure 1). The estimated community prevalence of vitamin D deficiency was 58.8 (95% CI: 53.5-64.1) %, vitamin D insufficiency was 31.4 (26.4-36.5) % and cumulative prevalence of deficiency and insufficiency was 90.2 (87.2 – 93.2) %. Females had a higher vitamin D deficiency prevalence (65 (95% CI: 58.8 – 71.1) %) compared to males (45 (35.2 – 54.8) %). On the other hand, females' vitamin D sufficiency prevalence (6.6 (3.6 – 9.6) %) was significantly less compared to males (16.8 (10.0 – 23.7) %). The vitamin D sufficiency in females over 60 years were only 3.5 (0.0 – 8.0) % which is significantly less than male over 60 years (30.3 (15.7 – 44.9) %). Interestingly, the highest vitamin D deficiency rate was noted in 18-40 age group at the community level (i.e. 65.9% (95% CI: 56.2-75.5)) and among males and females (Table 1).

Moors showed significantly less prevalence of vitamin D sufficiency compared to Sinhalese (3.4 (0.1 – 6.5) % vs 12.9 (8.7 – 17.1) %) Moors and Tamils had significantly lower vitamin D levels compared to Sinhalese but there was no difference between moors versus Tamils in vitamin D levels. People with family history of diabetes showed lower vitamin D levels and those who currently consumed alcohol and ex-alcohol consumers showed higher vitamin D levels compared to non-alcohol consumers but there was no significant difference between current alcohol consumers and ex-consumers.

Vitamin D deficiency/insufficiency and its demographic and Metabolic associations:

Population metabolic characteristics were analyzed according to their Vitamin D status. Body fat percentage was highest among vitamin D deficient group (37.4 (29.8 – 41.2) %) and lowest among vitamin D sufficient group (33.9 (28.0 - 38.0) %), but visceral fat percentage had not followed the same pattern. No major difference in BMI among these groups were noted. Unexpectedly, lowest waist circumference (84.0 (76.0 – 94.0) was seen in Vit D deficient group and highest (89.2 (80.9 – 96.2)) was seen in Vit D sufficient group.

Mean lipid levels were highest (Total cholesterol - 208.8(182.6- 239.2), LDL - 121.5 (98.2 – 147.1), Triglycerides - 133.4 (95.6 – 171.8) in the Vitamin D deficient group, including HDL levels. (Table 2)

Study population was categorized into BMI categories according to South Asian and global cut offs and their Vitamin D levels were compared. Under both categorizations, obesity group had the lowest mean Vit D levels (19.73, 18.49), while underweight group had the highest mean Vit D levels (21.63, 21.63). Difference in Vitamin D levels among obese vs others was statistically significant when the global cut offs were used for categorization (Table 3)

Initial individual variable analysis with simple linear regression showed gender, ethnicity, family history of diabetes, smoking, alcohol consumption, waist circumference, body fat percentage and TG were significantly associated with vitamin D levels. Multiple linear regression analysis showed, ethnicity, family history of diabetes, alcohol consumption, waist circumference, and TG levels were significantly associated with vitamin D levels (Table 4).

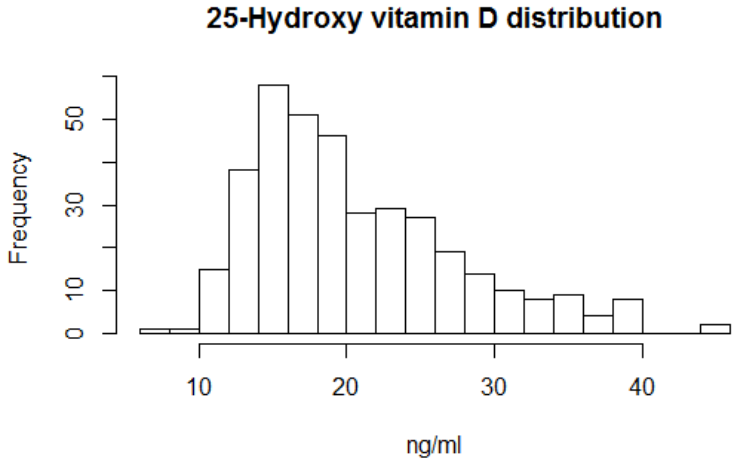

Figure 1. Distribution of 25-Hydroxy vitamin D levels in the community

Table 1. Estimated community prevalence of vitamin D status

	Vit D deficiency	Vit D insufficiency	Vit D sufficiency
Both sexes			
Community	58.8 (53.5-64.1)	31.4 (26.4-36.5)	9.8(6.7-12.7)
18-40	65.9 (56.2-75.5)	28.4 (19.1-37.7)	5.7 (9.2-10.4)
41-60	52.1 (45.3-58.9)	35.3 (28.7-41.8)	12.6 (8.1-17.2)
60 >	58.9 (49.4-68.3)	27.8 (19.2-34.4)	13.3 (6.8-19.9)
Males			
Community	45.0 (35.2-54.8)	38.1 (28.6-47.8)	16.8 (10.0-23.7)
18-40	48.1 (29.6-66.7)	40.7 (22.5-59.0)	11.1 (0.0-22.8)
41-60	42.9 (30.4-55.3)	39.3 (27.0-51.6)	17.9 (8.2-27.5)
60 >	42.4 (26.7-58.1)	27.3 (13.1-41.4)	30.3 (15.7-44.9)
Females			
Community	65.0 (58.8-71.1)	28.4 (22.6-34.2)	6.6 (3.6-9.6)
18-40	73.8 (62.9-84.6)	23.0 (12.6-33.3)	3.2 (0.0-7.7)
41-60	56.0 (47.9-64.1)	33.6 (25.9-41.3)	10.4 (5.5-15.4)
60 >	68.4 (57.2-79.6)	28.1 (17.2-38.9)	3.5 (0.0-8.0)

Table 2. Metabolic characteristics based on Vit D status

	Vitamin D deficiency	Vit D insufficiency	Vit D sufficiency
BMI	26.2 (22.3 - 29.5)	25.0 (22.0 -28.0)	26.6 (21.6 – 27.8)
Waist circumference	84.0 (76.0 – 94.0)	87.0 (79.0 – 95.7)	89.2 (80.9 – 96.2)
Neck circumference	33.0 (32.0 – 35.5)	34.0 (32.0 – 36.0)	34.0 (32.0 – 37.2)
Total body fat	37.4 (29.8 – 41.2)	35.2 (28.2 - 39.5)	33.9 (28.0 - 38.0)
Visceral body fat	9.0 (6.0 – 12.5)	9.0 (6.0 -12.0)	10.0 (4.0 – 10.0)
TC	208.8(182.6- 239.2)	204.9(181.8- 238.7)	205.5(163.8- 231.2)
LDL	121.5 (98.2 – 147.1)	121.7 (93.4 – 151.9)	113.1 (87.9 – 139.8)
TG	133.4 (95.6 – 171.8)	123.5 (94.1 – 155.4)	107.5 (87.8 – 123.5)
HDL	59.2 (54.2 – 63.4)	59.8 (54.9 – 64.3)	57.7 (51.5 – 64.7)
FBS	88.4 (81.2 – 103.7)	90.3 (82.2 – 104.8)	91.1 (84.1 – 99.3)
HbA1c	5.8 (5.5 – 6.6)	5.9 (5.5 – 6.8)	5.9 (5.5 – 6.4)
SBP	120.0 (11.0 – 130.0)	120.0 (110.0 – 130.0)	120.0 (110.0 – 130.0)
DBP	80.0 (70.0 – 81.2)	80.0 (70.0 – 85.0)	80.0 (80.0 – 80.0)
TSH	1.5 (0.9 – 2.5)	1.3 (0.8 – 2.1)	1.2 (0.7 – 1.8)
Serum Calcium	2.2 (2.1 – 2.3)	2.2 (2.1 – 2.3)	2.2 (2.1 – 2.3)

Table 3. Vitamin D levels according to BMI categories

	Mean Vit D level	Median Vit D level (Interquartile Range)	P value
South Asian BMI Categories			
Underweight	21.63	18.71(14.89-23.70)	
Normal	21.23	19.77(16.27-25.47)	
Overweight	21.05	18.98(16.09-24.71)	
Obese	19.73	18.05(14.47-24.00)	
Global BMI Categories			
Underweight	21.63	18.71(14.89-23.70)	
Normal	20.95	19.28(16.07-24.90)	
Overweight	21.21	19.38(15.67-25.31)	
Obese	18.49	16.75(14.20-22.12)	
Obese vs underweight			0.02045
Obese vs normal			0.00999
Obese vs overweight			0.05745

Table 4. Parameter estimates

Parameter	Estimate	Standard error	t value	P value
Intercept	17.007392	2.272763	7.483	<0.01
Ethnicity				
Sinhalese vs Tamils	-1.708632	0.994072	-0.176	0.09
Sinhalese vs Moors	-3.250352	0.910397	-3.570	<0.01
Sinhalese vs others	-0.804684	4.576572	-0.176	0.86
Family history of diabetes	-1.879279	0.690879	-2.720	<0.01
Alcohol consumption				
None vs current consumers	4.146291	0.944381	4.390	<0.01
None vs ex-consumers	5.369811	1.533552	3.502	<0.01
Waist circumference	0.088292	0.026845	3.289	<0.01
Triglyceride levels	-0.023763	0.005116	-4.644	<0.01

Discussion

This study population with mixed ethnic and social characteristics from an urban setting in Sri Lanka showed very high cumulative estimated community prevalence of vitamin D deficiency and insufficiency [90.2 (87.2 – 93.2) %.]. This is comparable with South Asian regional prevalence (70-100%) (1-5) and clinical anticipation of high prevalence, while it is much higher than the reported prevalence of vitamin D deficiency in previously published data from Sri Lankan studies (8,9). Sun exposure is the major source of vitamin D, as very few naturally occurring food are rich in Vitamin D. This high prevalence despite ample sunshine throughout the year in the country could be possibly explained by the darker skin complexion, sunscreen use, less outdoor activities, lack of food fortification with vitamin D (6,7). Defining vitamin D deficiency based on international cut off may also play a role in finding high prevalence (21,22). Further studies on clinical significance of this biochemical diagnosis and defining local cut off and diagnostic criteria would be useful.

This problem was seen throughout all three age strata including younger population less than 40 years. Female gender and Moor ethnicity were recognized groups with high prevalence, but only ethnicity was significantly associated with vitamin D deficiency. Clothing and other cultural, social factors associated with Moor ethnicity have shown to be associated with high levels of vitamin D deficiency globally, especially in Muslim dominant countries in the South Asian region (1-5). Interestingly, it was found that vitamin D deficiency prevalence is highest among young, aged 18-40 years than older age group, where the efficiency of vitamin D biosynthesis is believed to decrease due to many factors. Some previous studies from Asia had showed similar results (23-25). This could be explained by rapid economic development and changing job patterns in recent past in urban setting which has resulted in young adults having indoor jobs, while elderly adults tend to have outdoor jobs as well have more time for other outdoor activities (24,25). This finding is significant as the peak bone mass which determines the future bone health is achieved at this age group.

In this population, alcohol consumption was positively associated with Vitamin D levels. Data concerning alcohol use and vitamin D remains controversial in literature. Recent literature review on this topic reported heterogeneous results, with a similar number of papers indicating a positive association, a negative association or the absence of any association between alcohol use and vitamin D levels (28). Several explanations have been given for negative association but exact biochemical explanation for positive association is not known. A speculative explanation given to this is that alcohol could suppress parathyroid hormone (PTH) levels and therefore 25 hydroxy Vitamin D (25OH vit D) is elevated as a result of reduced vitamin D activation in kidney, causing high measurable vitamin D levels (26).

Obesity is a known association of Vitamin D deficiency. In this population as well, obese category showed the lowest vitamin D levels compared to others. Their Vit D levels were significantly lower than in others, when global BMI cut offs, which are higher than the South Asian cut offs were used for categorization. Obesity and metabolic syndrome are emerging major health problems in the country at the moment (27,28) and this co existent Vitamin D deficiency will add to its health burden. Waist circumference, which is a measure of abdominal obesity did not correlate with Vit D levels in the expected manner in this population.

Total cholesterol, Triglyceride levels and LDL levels were highest in the Vit D deficient group, but only Triglyceride showed a significant association. This is a known association from Vitamin D studies conducted all around the world and this adverse association has been even seen among children with Vit D deficiency. Several mechanisms have been postulated for this. Serum Ca can reduce hepatic TAG production and secretion while low PTH levels could enhance peripheral TAG removal. Vitamin D deficiency associated low Ca absorption and PTH elevation are thought to cause high TAG levels (29,30). Other studies have also shown significant associations with total cholesterol, LDL and HDL with increased atherogenic risk (29).

Despite high prevalence of dysglycaemia, this study population did not show any significant association with the vitamin D status, which has been described in many observational studies and pre-clinical data over last decade (13-16). In that context it was hypothesized that vitamin D repletion would reduce Diabetes risk but results from randomized trials on this hypothesis were inconsistent (13-16). Recently published randomized, double-blind, placebo controlled D2d trial also showed no significant Diabetes risk reduction (31), and therefore it is not surprising to find no association between DM and vitamin D in our population.

Conclusion

This study reported very high prevalence of vitamin D deficiency and insufficiency in an urban setting in Sri Lanka across all age strata, which exceeds 90%. Moor ethnicity was the main recognized demographic association. Obese had significantly lower Vit D levels. Triglyceride levels were negatively correlated with vitamin D levels, but other metabolic derangements including diabetes showed no significant association with vitamin D status in the given population.

Clinical and skeletal outcomes of vitamin D deficiency/ insufficiency, as well, contribution of nutritional factors and extent of sun exposure for this condition should be extensively studied in the future with the view of planning interventions to prevent this problem and replete the vitamin D

status. Further studies to define local cut off and diagnostic criteria for vitamin D deficiency will be useful to identify the true burden of this problem on our population.

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Declarations:

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Ethics approval and consent to participate

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Competing interests

None of the authors have any financial or non-financial competing interests to disclose.

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Authors' contributions

NPS, KG involved in designing the study and data collection. CJS and DE analysed the data. CJS drafted the manuscript and all other authours read and approved it.

Availability of data and materials

The data analysed in this paper can be made available to researchers. Requests for access to the data set used in this paper should be directed to the corresponding author.