Vitamin D status of overweight and obese Bangladeshi adults

Ajit K. Paul¹, A. B. M. Kamrul-Hasan², Palash K. Chanda², Dulal C. Nandi³

¹Department of Endocrinology, Mainamoti Medical College, Cumilla, ²Department of Endocrinology, Mymensingh Medical College Hospital, Mymensingh, ³Department of Statistics, Cumilla University, Cumilla, Bangladesh

Abstract

Background: Both obesity and vitamin D deficiency are pandemics and both have influences on cardiovascular parameters. The reported prevalence of vitamin D deficiency in obesity is high. Data relating to vitamin D status in obese is currently lacking in Bangladesh. Objective: To discover the vitamin D status in Bangladeshi overweight and obese adults. Subjects and Methods: This cross-sectional study, conducted in a specialized endocrine center of Bangladesh, evaluated 500 consecutive overweight or obese subjects, diagnosed according to body mass index (BMI) categories applicable to the south Asian population. Serum 25(OH)D was measured by using the enzyme-linked fluorescent assay (ELFA) method, and the cutoffs described by the Endocrine Society were used to define vitamin D status. Results: The mean age of the study subjects was 45.85 (±11.41) years; most (59.6%) of them were in the age group 40–59 years; almost three-fourth (72.4%) were females; an almost equal number of them came from urban (33.8%), semi-urban (29.6%), and rural (36.6%) areas; three-fourth (74.2%) were homemaker. Their mean BMI was 29.54 (±3.11) kg/m²; the frequencies of overweight, class I obesity, class II obesity, and class III obesity were 27.6%, 57.4%, 12.2%, and 2.8%, respectively. The mean serum 25(OH)D level was 25.25 (±11.97) ng/mL. 27.4% were sufficient, and 33.4% were insufficient for vitamin D, whereas 39.2% had vitamin D deficiency. The 25(OH)D levels were also indifferent in overweight, obese class I, obese class II, and obese class III subjects. None of the demographic, anthropometric, and biochemical variables (except low-density lipoprotein cholesterol) correlated with 25(OH)D levels. Conclusions: The prevalence of vitamin D deficiency in overweight and obese Bangladeshi adults is very high.

Keywords: Body mass index, blood pressure, obesity, overweight, vitamin D

Introduction

Obesity is a global pandemic; overall, about 13% of the adult population (11% of men and 15% of women) of the world were obese in 2016. Moreover, 39% of adults (39% of men and 40% of women) were overweight in 2016.[1] In the last 40 years (between 1975 and 2016), the prevalence of obesity nearly tripled worldwide.[2] Once associated with high-income countries, obesity is now also prevalent in low- and middle-income countries.[1] In a study conducted in 2011, the prevalence of overweight and obesity in adults aged 35–70 years in different cities of Bangladesh found was 18.9% (male 17.4% and female 18.4%) and 4.6% (male 3.0% and female 6.0%), respectively.[3] Another population-based, cross-sectional survey conducted in 2009 reported that the prevalence of overweight and obesity was 17.7% and 26.2%, respectively, in rural Bangladeshi adults.[4] Obesity is associated with several comorbidities such as cardiovascular (CV) disease, hypertension (HTN), stroke, type 2 diabetes mellitus (T2DM), dyslipidemia, osteoarthritis, and some cancers.[5] Around 2.8 million people are dying each year as a result of being overweight or obese.[6]
Serum concentrations of 25-hydroxyvitamin D [25(OH)D] are considered as the best indicator of total body vitamin D stores. The association between reduced 25(OH)D concentrations and obesity is well known, but the mechanisms are not fully understood. Many clinical and epidemiological studies reported that obese subjects have lower serum concentrations of 25(OH)D and higher prevalence of vitamin D deficiency with a negative correlation of vitamin D concentrations with waist circumference (WC) and body mass index (BMI). In a meta-analysis, the prevalence of vitamin D deficiency was 35% higher in obese subjects compared to the eutrophic group and 24% higher than in the overweight group. One “superfluous” BMI unit is known to induce a 1.15% reduction in the 25(OH)D concentration. Evidence also supports the inverse association of fat mass with 25(OH)D levels.

In Bangladesh, previous studies have reported a high prevalence of vitamin D deficiency in various subsets of the population. Obesity is also a common problem here encountered by both primary care physicians and specialists. Data relating to vitamin D status in obese are currently lacking in this country; we conducted this study to fill this knowledge gap.

Subjects and Methods

Study area

This cross-sectional study was conducted in the endocrinology outpatient department of Cumilla Diabetic Hospital located at Cumilla, a district town located in the South-East part of Bangladesh, from January 2017 to December 2018.

Study subjects

All consecutive subjects having overweight or obesity attending the endocrine center were included in the study sample. The subjects who had an acute illness, hepatic or renal dysfunction, malabsorption, debilitating chronic disease, and those who got vitamin D or a calcium supplement in the previous 3 months, vegans, pregnant and lactating women were excluded. Finally, 500 overweight or obese subjects fulfilling the inclusion and exclusion criteria were investigated.

Clinical assessment

A semi-structured questionnaire-based interview on a one-to-one basis was conducted to collect data. Socio-demographic data were collected, and anthropometric measurements were done for all. Height (to ± 0.1 cm) was measured in all the individuals using wall-mounted stadiometers, and body weight (to ± 0.1 kg) measured using electronic calibrated scales; BMI was calculated from height and weight using the formula: height/weight² and BMI categories applicable to the south Asian population was used to define obesity status.

Blood pressure was measured two times in every study subject by the auscultatory method using standard validated aneroid sphygmomanometer after at least 5 min of rest; two separate readings were taken at an interval of a minimum of 3 min, and the average of the two readings was used.

Biochemical assay

Venous blood was collected from each subject. Serum 25(OH)D was measured by the auto analyzer VIDAS (Marcy l’Etoile, France) using the enzyme-linked fluorescent assay (ELFA) method. 25(OH)D levels were considered normal (≥30 ng/mL), insufficient (>20 to 29.9 ng/mL), and deficient (≤20 ng/mL) as per Clinical Practice Guidelines, 2011 of the Endocrine Society. Lipid profile was measured in all fasting states using fully automatic biochemistry analyzers.

Ethical issues

The institutional review board of the hospital approved the study protocol on 26 December, 2016. Informed written consent was taken from all of the study participants before clinical and laboratory assessments. The privacy of the study subjects was maintained throughout the study procedure. Data were anonymous, and only a number was expressed against each subject.

Statistical analysis

Data were analyzed using Statistical Packages for Social Sciences (SPSS) for Windows, version 23.0 software (SPSS Inc; Chicago, IL, USA). The categorical variables were represented as percentages and measurable variables as mean ± SD or median. Student’s t-test and one-way analysis of variance (ANOVA) were performed for comparing the variables between different groups as appropriate. Pearson’s correlation test was used to observe the correlation of vitamin D levels with other variables. P value ≤0.05 was considered to be statistically significant.

Results

The demographic, clinical, and biochemical parameters of the study subjects are given in Table 1. Their mean age was 45.85 (±11.41) years; most (59.6%) of them were in the age group 40–59 years; almost three-fourth (72.4%) were females; an almost equal number of them came from urban (33.8%), semi-urban (29.6%), and rural (36.6%) areas; more than half (59.2%) got education up to the primary level; three-fourth (74.2%) were homemakers; less than half had a monthly income ≥20,000 BDT. Their mean BMI was 29.54 (±3.11) kg/m²; the frequency of overweight, class I obesity, class II obesity, and class III obesity were 27.6%, 57.4%, 12.2%, respectively.
Table 1: General characteristics of the study participants (n=500)

| Variables                | Subgroups | Mean±SD or n (%) |
|--------------------------|-----------|------------------|
| Age (years)              | 45.85±11.41 |
| Age group (years)        | 20-39: 140 (28.0), 40-59: 298 (59.6), 60 & above: 62 (12.4) |
| Gender                   | Male: 138 (27.6), Female: 362 (72.4) |
| Residence                | Urban: 169 (33.8), Suburban: 148 (29.6), Rural: 183 (36.6) |
| Education                | Primary level or less: 296 (59.2), Secondary level: 85 (17.0), Higher secondary level: 66 (13.2) |
| Occupation               | Homemaker: 371 (74.2), Office job: 93 (18.6), Business: 36 (7.2) |
| Monthly income (BDT)     | Up to 10,000: 122 (24.4), >10,000 to <20,000: 139 (27.8), 20,000 & above: 239 (47.8) |
| Weight (Kg)              | 71.19±9.74 |
| Height (Meter)           | 1.55±0.07 |
| BMI (kg/m2)              | 29.54±3.11 |
| Obesity category         | Overweight: 138 (27.6), Obese class I: 287 (57.4), Obese class II: 61 (12.2), Obese class III: 14 (2.8) |
| Systolic BP (mmHg)       | 125±14 |
| Diastolic BP (mmHg)      | 80±6 |
| Triglyceride (mg/dL)     | 144±53 |
| Total cholesterol (mg/dL)| 167±73 |
| LDL cholesterol (mg/dL)  | 130±54 |
| HDL cholesterol (mg/dL)  | 60±15 |
| Serum 25(OH)D (ng/mL)    | 25.25±11.97 |

Figure 1 depicts the vitamin D status of the study participants; 27.4% were sufficient, and 33.4% were insufficient of vitamin D, whereas 39.2% of them had vitamin D deficiency.

The comparison of 25(OH)D level in various subgroups of the study subjects are given in Table 2. The study subjects in the different age groups, gender, residence, education status, occupation, and income status, had similar 25(OH)D levels. 25(OH)D levels were also indifferent in overweight, obese class I, obese class II, and obese class III subjects.

Correlations of 25(OH)D level with other variables are shown in Table 3. Only LDL cholesterol (LDL-C) showed a significant positive correlation with vitamin D level.

Discussion

In this study conducted among the overweight and obese patients attending a specialized endocrine center of Bangladesh, we observed that their mean BMI was 29.54 (±3.11) kg/m²; the frequency of overweight, class I obesity, class II obesity, and class III obesity were 27.6%, 57.4%, 12.2%, and 2.8%, respectively. The mean serum 25(OH)D level was 25.25 (±11.97) ng/mL; 27.4% were sufficient, and 33.4% were insufficient of vitamin D, whereas 39.2% of them had vitamin D deficiency.

Both obesity and vitamin D deficiency are pandemic conditions, and both of them are related to some common adverse outcomes, most importantly, adverse cardio-metabolic outcomes.[24]

Moreover, obese people have lower serum 25(OH)D than normal-weight people, and serum 25(OH)D is inversely correlated with body weight, BMI, and fat mass. This has been shown in many clinical and epidemiological studies conducted in different countries of the world. The prevalence of 25(OH)D deficiency is greater in obese people, reported at between 40 and 80%.[9‑16] Studies reported that, serum 25(OH)D is about 20% lower in obese people than normal weight.[24] Low serum 25(OH)D is more likely a consequence of obesity, rather than the cause of obesity. A large genetic study found that high BMI and genes that predispose to obesity decrease serum 25(OH)D. In contrast, low 25(OH)D and genes associated with low 25(OH)D have minimal effect on obesity.[17] The underlying mechanisms of hypovitaminosis D in obesity is not clear. There could be lower vitamin D input because of lower dietary intake, lower sunlight exposure, or impaired skin synthesis of vitamin D. Alterations in protein binding or faster metabolic clearance in obesity could lead to lower serum 25(OH)D. The lower serum 25(OH)D could be because of the distribution of 25(OH)D into a larger whole-body tissue volume, particularly if 25(OH)D were actively sequestered in other tissues.[24]

The vitamin D status of the general population is not well studied in Bangladesh. Few small scale studies had observed...
Paul, et al.: Vitamin D in overweight and obese

A high prevalence of hypovitaminosis D in this country. In a study, Kamrul-Hasan et al. found all of the healthy women of reproductive age to have hypovitaminosis D (12% insufficient and 88% deficient). Among the 212 study populations of different age groups, all were found to be vitamin D deficient in another study conducted by Hossain et al. Islam et al., in a laboratory-based study of 793 samples, found that 61.4% had vitamin D deficiency, and 24.1% had insufficiency, vitamin D level was found sufficient in 13.1% subjects. In the current study, the frequency of hypovitaminosis D (72.6%, insufficiency 33.4%, and deficiency 39.2%) was lower than the previous observations. In the absence of vitamin D status of the general population of the country and lack of an otherwise healthy normal-weight control group in the current study, it is tough to comment on the relative status of vitamin D in our study subjects. In this context, the frequency of vitamin D deficiency, insufficiency, and sufficiency among Turkish obese patients without metabolic syndrome observed by Karatas et al. were 69.2%, 17.5%, and 13.3%, respectively. Taheri et al. found that 79% of Iranian obese otherwise healthy subjects to suffer from vitamin D deficiency or insufficiency.

A negative correlation between serum 25(OH)D levels and BMI has been observed by many researchers. We also observed a negative correlation between serum 25(OH)D levels and BMI, though it was not statistically significant. The 25(OH)D levels were also similar in different obesity categories in this study. Palazhy et al. noticed no direct correlations between BMI and 25(OH)D level. We found no correlations of 25(OH)D levels with body weight and height. In a study on 250 overweight and obese adults of different ethnicities, McGill et al. demonstrated that the serum level of vitamin D3 was inversely related to weight.

Age is an important factor affecting 25(OH)D levels, and a decline in 25(OH)D levels has been reported with advancing age. We observed no differences in 25(OH)D levels among the different age groups, and 25(OH)D levels did not correlate with age. Similarly, another study in Bangladesh found no significant difference of 25(OH)D levels between age groups <40 years and ≥40 years. On the contrary, Palazhy et al. and Al Zarooni et al. found 25(OH)D levels to be increased with increasing age.

Our study observed no significant difference of 25(OH)D level between males and females; this is in agreement with the observations of Alam et al. and Palazhy et al. On the contrary, women had higher vitamin D compared to men in an Indian study.

#### Table 2: Comparison of 25(OH)D level in various subgroups of the study subjects

| Variables          | Subgroups     | Serum 25(OH)D level (ng/mL, mean±SD) | P     |
|--------------------|---------------|-------------------------------------|-------|
| Age group (years)  | 20-39         | 24.89±11.99                         | 0.742 |
|                    | 40-59         | 25.58±12.02                         |       |
|                    | 60 & above    | 24.97±11.81                         |       |
| Gender             | Male          | 25.51±12.68                         | 0.770 |
|                    | Female        | 25.16±11.71                         |       |
| Residence          | Urban         | 25.62±12.87                         |       |
|                    | Suburban      | 25.30±11.54                         | 0.841 |
|                    | Rural         | 24.87±11.50                         |       |
| Education          | Primary level or less | 25.45±11.76 | 0.453 |
|                    | Secondary level | 26.53±13.78 |       |
|                    | Higher secondary level | 23.84±11.29 |       |
|                    | Graduate and higher level | 23.90±10.82 |       |
| Occupation         | Homemaker     | 25.16±11.68                         | 0.738 |
|                    | Office job    | 25.07±13.27                         |       |
|                    | Business      | 26.75±11.67                         |       |
| Monthly income (BDT)| Up to 10,000 | 24.70±12.19                         | 0.555 |
|                    | >10,000 to <20,000 | 26.17±10.97 |       |
|                    | 20,000 & above | 25.00±11.97 |       |
| Obesity category   | Overweight    | 26.08±13.48                         | 0.820 |
|                    | Obese class I | 24.97±11.67                         |       |
|                    | Obese class II| 24.73±10.54                         |       |
|                    | Obese class III| 25.25±11.97 |       |

P-value by student's t-test or one-way ANOVA, as applicable

#### Table 3: Correlations of 25(OH)D level with other variables

| Variables          | r   | P   |
|--------------------|-----|-----|
| 25(OH)D and age    | 0.010| 0.825|
| 25(OH)D and height | 0.000| 0.999|
| 25(OH)D and weight | -0.027| 0.547|
| 25(OH)D and BMI    | -0.025| 0.573|
| 25(OH)D and systolic BP| 0.043| 0.339|
| 25(OH)D and diastolic BP | 0.014| 0.750|
| 25(OH)D and LDL-C  | 0.100| 0.025|
| 25(OH)D and HDL-C  | -0.073| 0.103|
| 25(OH)D and TG     | -0.015| 0.740|
| 25(OH)D and TC     | 0.034| 0.445|

by Pearson correlation test
conducted among the general population. Serum vitamin D levels were similar among subjects residing in rural, suburban, and urban areas in this study. Al Zarooni et al. also found no difference in mean vitamin D level concentration between the urban and suburban areas. The urban residents had the highest levels of 25(OH)D, followed by rural residents and the lowest for large metro residents in the American population in a study done by Bailey et al. The community in which the participants belonged did not have any significant influence on the vitamin D level, according to Tangoh et al., indicating that the level of urbanization may not affect vitamin D status. 25(OH)D levels were indifferent across different levels of educational qualification and income status in the current study. Subjects with a higher level of education had lower 25(OH)D levels in a study done by Al Zarooni et al. There was no significant difference in vitamin D levels between levels of education and income levels in another study by Tangoh et al.

In this study, 25(OH)D levels did not correlate with either systolic or diastolic BP. Karatus et al. had similar observations in obese subjects, Alam et al. also found no differences in vitamin D level among the among normotensive, borderline hypertensive, and hypertensive subjects with DM. On the other hand, Kota et al. demonstrated that systolic blood pressure, diastolic blood pressure, and mean arterial pressure was increased among individuals experiencing inadequacy of vitamin D. Most of the observational studies demonstrated the association of lower circulating 25(OH)D levels with higher blood pressures or a higher prevalence of hypertension.

In this study, 25(OH)D levels did not correlate with either total cholesterol, HDL cholesterol, or triglyceride levels; only LDL cholesterol showed a significant positive correlation with vitamin D level. Karatus et al. also observed no correlations of vitamin D with triglyceride and HDL cholesterol levels in obese subjects. In the Indian population, Chaudhuri et al. reported that 25(OH)D deficiency was independently associated with dyslipidemia. The serum 25(OH)D levels were inversely associated with TG and LDL-C and positively associated with TC in Chinese adults.

Limitations of the study

Our study had several limitations. It was a single-center study, and the sample size was small, which may not reflect the scenario of the whole country. No control group was evaluated, so comparison with the vitamin D status of the normal-weight healthy population could not be made. The seasonal variations in vitamin D levels and the extent of sun exposure of the study subjects were not taken into account. WC was not measured, limiting the influence of abdominal obesity on vitamin D status. We did not measure plasma glucose, glycated hemoglobin, and the markers of insulin resistance like fasting insulin level and HOMA-IR. Due to a lack of availability, it was not possible to measure 25(OH)D using the reference standard methods, e.g., liquid chromatography-mass spectrometry (LC-MS) and mass spectrometry (MS). Serum calcium, inorganic phosphate, parathormone, and other markers of calcium metabolism were also not assessed. Therefore the result of the study may not be conclusive.

Conclusion

The prevalence of vitamin D deficiency in overweight and obese Bangladeshi adults is very high (72.6%; 33.4% insufficient, 39.2% deficient) according to this study result. No correlations were observed between vitamin D levels and age, BMI, blood pressure, and serum lipids except LDL cholesterol, which had a positive correlation with vitamin D level. However, a large-scale population-based study, including the normal weight otherwise healthy comparison group, should be conducted to explore the vitamin D status in our population.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. World Health Organization. 6 Facts on Obesity. Available from: https://www.who.int/news-room/facts-pictures/detail/6-facts-on-obesity. [Last assessed on 2020 Mar 18].
2. World Health Organization. Fact Sheet Obesity and Overweight. Available from https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight. [Last assessed on 2020 Mar 18].
3. Biswas T, Garnett SP, Pervin S, Rawal LB. The prevalence of underweight, overweight and obesity in Bangladeshi adults: Data from a national survey. PLoS One 2017;12:e0177395.
4. Siddiquie T, Bhowmik B, Da Vale Moreira NC, Mujumder A, Mahtab H, Khan AK, et al. Prevalence of obesity in a rural Asian Indian (Bangladesh) population and its determinants. BMC Public Health 2015;15:860.
5. Cardel MI, Jastreboff AM, Kelly AS. Treatment of adolescent obesity in 2020. JAMA 2019;322:1707-8.
6. Pereira-Santos M, Costa PR, Assis AM, Santos CA, Santos DB. Obesity and vitamin D deficiency: A systematic review and meta-analysis. Obes Rev 2015;16:341-9.
7. SokšiŠ S, StokšiŠ E, Isenoviš ER. The relationship between vitamin D and obesity. Curr Med Res Opin 2014;30:1197-9.
8. Holick MF. Vitamin D deficiency. N Engl J Med 2007;357:266-81.
9. Taheri E, Saedisomealia A, Djalali M, Qorbani M, Madani Civie M. The relationship between serum 25-hydroxy vitamin D concentration and obesity in type 2 diabetic patients and healthy subjects. J Diabetes Metab Disord 2012;11:16.

10. Jungert A, Roth HJ, Neuhauser-Berthold M. Serum 25-hydroxyvitamin D3 and body composition in an elderly cohort from Germany: A cross-sectional study. Nutr Metab (Lond) 2012;9:42.

11. Parikh SJ, Edelman M, Uwaifo GI, Freedman RJ, Semega-Jannmeh M, Reynolds J, et al. The relationship between obesity and serum 1,25-dihydroxy vitamin D concentrations in healthy adults. J Clin Endocrinol Metab 2004;89:1196-9.

12. Karatas S, Hekimsoy Z, Dinc G, Onur E, Ozmen B. Vitamin D levels in overweight/obese adults with and without metabolic syndrome. J Endocrinol Metab 2013;3:47-56.

13. Young KA, Engelman CD, Langefeld CD, Hairston KG, Haffner SM, Bryer-Ash M, et al. Association of plasma vitamin D levels with adiposity in Hispanic and African American adults. J Clin Endocrinol Metab 2009;94:3306-13.

14. Konradsen S, Ag H, Lindberg F, Hvitberg S, Jorde R. Serum vitamin D status: bi-directional Mendelian randomization analysis of multiple cohorts. PLoS Med 2013;10:e1001383.

15. Rodriguez-Rodriguez E, Navia B, Lopez-Sobaler AM, Ortega RM. Vitamin D in overweight/obese women and its relationship with dietary and anthropometric variables. Obesity (Silver Spring) 2009;17:778-82.

16. Wortsman J, Matsuoka LY, Chen TC, Lu Z, Holick MF. Decreased bioavailability of vitamin D in obesity. Am J Clin Nutr 2000;72:690-3.

17. Vimaaleswaran KS, Berry DJ, Lu C, Tikkanen E, Tikkanen M, et al. Causal relationship between obesity and vitamin D status: bi-directional Mendelian randomization analysis of multiple cohorts. PLoS Med 2013;10:e1001383.

18. Arunabha S, Pollock S, Yeh J, Aloja JF. Body fat content and 25-hydroxyvitamin D levels in healthy women. J Clin Endocrinol Metab 2003;88:157-61.

19. Kamrul-Hasan AB, Aalpona FZ, Chanda PK, Ariful-Islam M, Palash-Molla M, Rabaya-Akter M, et al. Vitamin D status in polycystic ovarian syndrome patients attending a tertiary hospital of Bangladesh. Mymensingh Med J 2018;27:730-6.

20. Hessain HT, Islam QT, Khandaker MAK, Ahsan HN. Study of serum vitamin D level in different socio-demographic population-A pilot study. J Med Ed 2018;19:22-9.

21. Alam MS, Kamrul-Hasan M, Kalam ST, Selim S, Akter F, Salifuddin M. Vitamin D status in newly diagnosed type 2 diabetes patients attending a tertiary hospital of Bangladesh. Mymensingh Med J 2018;27:362-8.

22. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 2004;363:157-63.

23. Holick MF, Binkley NC, Bischoff-Ferrari HA, Gordon CM, Hanley DA, Heaney RP, et al. Evaluation, treatment and prevention of vitamin D deficiency: An endocrine society clinical practice guideline. Clin Endocrinol Metab 2011;96:1911-30.

24. Walsh JS, Bowles S, Evans AL. Vitamin D in obesity. Curr Opin Endocrinol Diabetes Obes 2017;24:389-94.

25. Islam A, Hasan MN, Rahman K, Asaduzzaman M, Rahim MA, Zaman S, et al. Vitamin D status in Bangladeshi subjects: A laboratory based study. BIRDEM Med J 2019;8:202-6.

26. Palazhy S, Viswanathan V, Murugananthan A. Prevalence of 25-hydroxy vitamin D deficiency among type 2 diabetic subjects of South India. Int J Diabetes Dev Ctries 2017;37:69-73.

27. McGill AT, Stewart JM, Likhitter FE, Strik CM, Poppiat SD. Relationships of low serum vitamin D3 with anthropometry and markers of the metabolic syndrome and diabetes in overweight and obesity. Nutr J 2008;7:4.

28. Scragg R, Sowers M, Bell C, Third National Health and Nutrition Examination Survey. Serum 25-hydroxyvitamin D, diabetes, and ethnicity in the Third National Health and Nutrition Examination Survey. Diabetes Care 2004;27:2813-8.

29. Al Zarooni AAR, Al Marzouqi FI, Al Darmaki SH, Prinsloo EAM, Nagelkerke N. Prevalence of vitamin D deficiency and associated comorbidities among Abu Dhabi Emirates population. BMC Res Notes 2019;12:503.

30. Harinarayanan CV, Ramalakshmi T, Venkatara PV. High prevalence of low dietary calcium and low vitamin D status in healthy south Indians. Asia Pac J Clin Nutr 2000;72:690-3.

31. Bailey BA, Manning T, Peiris AN. The impact of living in rural and urban areas: Vitamin D and medical costs in veterans. J Rural Health 2012;28:356-63.

32. Tangoh DA, Apinjoh TO, Mahmood Y, Nyingchuu RV, Tangunyi BA, Nji EN, et al. Vitamin D status and its associated risk factors among adults in the southwest region of Cameroon. J Nutr Metab 2018;2018:4742574.

33. Kota SK, Kota SK, Jammula S, Meher LK, Panda S, Tripathy PR, et al. Renin-angiotensin system activity in vitamin D deficient, obese individuals with hypertension: An urban Indian study. Indian J Endocrinol Metab 2011;15:395-401.

34. Vaidya A, Forman JP. Vitamin D and vascular disease: The current and future status of vitamin D therapy in hypertension and kidney disease. Curr Hypertens Rep 2012;14:111-9.

35. Chaudhuri JR, Mridula KR, Anamika A, Boddu DB, Misra PK, Lingalah A, et al. Deficiency of 25-hydroxyvitamin D and dyslipidemia in Indian subjects. J Lipids 2013;2013:623420.

36. Wang Y, Si S, Liu J, Wang Z, Jia H, Feng K, et al. The associations of serum lipids with vitamin D status. PLoS One 2016;11:e0165157.