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Association of Bone mineral density with serum vitamin D level in adult females of Bangladesh

Keya Sarker [1, *], Qazi Shamima Akhter [2], Manasi Saha [3], Swarnali Chakrabarty [4], Nishat Rahman [5], Nawshin Islam [6], Kaniz Fatema [7] and Mohammad Mostafizur Rahman [8]

[1] *Department of Physiology, Mugda Medical College, Dhaka, Bangladesh.*
[2] *Department of Physiology, Dhaka Medical College, Dhaka, Bangladesh.*
[3] *Department of Physiology, Rajshahi Medical College, Rajshahi, Bangladesh.*
[4] *Department of Physiology, Habigonj Medical College, Habigonj, Bangladesh.*
[5] *Department of Physiology, Z.H. Sikder Women's Medical College, Dhaka, Bangladesh.*
[6] *Department of Physiology, Mugda Medical College, Dhaka, Bangladesh.*
[7] *Department of Clinical Pathology, National Institute of Laboratory Medicine and Referral Center, Dhaka, Bangladesh.*
[8] *Department of Physiology, Shaheed Syed Nazrul Islam Medical College, Kishoreganj, Bangladesh.*

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Abstract

Background: Serum vitamin D level is considered to have impact on bone mineral density. Though low vitamin D level is prevalent worldwide as well as in our country among all age groups but the association of vitamin D level with bone mineral density is unclear.

Objective: To assess the association of serum vitamin D level with bone mineral density in adult female of Bangladesh.
Methods: This cross-sectional study was conducted at Dhaka Medical College from January to December 2019. Seventy adult females aged 18–44 years were enrolled based on predefined criteria. Bone mineral density of the lumbar spine and femoral neck was measured by dual-energy X-ray absorptiometry. Serum vitamin D and related biochemical parameters were analyzed from venous blood samples. Data were analyzed using SPSS version 26.0.

Results: In this study, mean (±SD) serum vitamin D of the study subjects was 22.13±2.6 ng/ml. The vitamin D sufficiency was found in 2.9% of the total study population and vitamin D insufficiency and deficiency was found in 75.7% and 21.4% of the total population respectively. The mean (±SD) BMD T score (lumbar spine) of the study subjects with vitamin D sufficiency, insufficiency and deficiency was -0.80±0.28, -0.09±0.81 and 0.28±0.91 respectively. The mean (±SD) BMD T score (femoral neck) of the study subjects with vitamin D sufficiency, insufficiency and deficiency was -0.25±0.07, -0.01±0.78 and -0.23±0.85 respectively.

Conclusions: According to the analysis of the results, the majority of the study subjects exhibited insufficient or deficient serum vitamin D levels without showing any association with bone mineral density.

Keywords: BMD; Vitamin D; Hypovitaminosis D; Adult females

1. Introduction

Bone is a specialized connective tissue that provides structural support, protects vital organs, facilitates movement, stores minerals, and plays a critical role in hematopoiesis[1]. Bone tissue consists of bone cells embedded in a dense

* Corresponding author: Keya Sarker

extracellular matrix composed of an inorganic mineral phase, primarily calcium salts, and an organic component mainly consisting of collagen[2]. Bone mineral density (BMD), defined as the amount of mineral content per unit area of bone, reflects bone strength and structural integrity. Peak bone mass is generally achieved in early adulthood, after which gradual bone loss occurs. Women typically have lower peak bone mass compared to men, making them more susceptible to reduced bone density and osteoporosis later in life[3].

Bone mineral density assessment is widely used to evaluate bone strength, predict fracture risk, and monitor skeletal health. Dual-energy X-ray absorptiometry (DXA) is the most reliable and commonly used method for measuring BMD[4]. The results are expressed as T-scores, which classify bone status into normal bone density, osteopenia, or osteoporosis based on established diagnostic criteria. Bone health is influenced by multiple factors that can be broadly categorized as non-modifiable and modifiable. Non-modifiable factors include age, sex, genetic predisposition, ethnicity, and body size[5]. Modifiable factors include nutritional status, physical activity, hormonal balance, lifestyle habits, and adequate levels of essential micronutrients, particularly vitamin D and calcium[6].

Vitamin D plays a crucial role in maintaining bone health by enhancing intestinal calcium absorption and regulating calcium and phosphate homeostasis, which are essential for bone mineralization. The active form of vitamin D facilitates the expression of calcium-transport proteins in the intestine, thereby supporting optimal skeletal mineralization[7]. Inadequate vitamin D levels can impair calcium absorption, disrupt bone remodeling, and potentially compromise bone strength. Vitamin D functions as a steroid hormone and exerts its biological effects through vitamin D receptors present in various tissues, including bone, intestine, kidney, and immune cells[8,9]. Beyond skeletal health, vitamin D deficiency has been associated with several systemic health consequences. In women of reproductive age, low vitamin D levels may adversely affect overall health and pregnancy-related outcomes[10]. Parathyroid hormone (PTH) also plays a key role in calcium and phosphate metabolism and bone remodeling. Reduced serum calcium levels stimulate PTH secretion, leading to increased bone resorption and potential bone loss. Chronic disturbances in vitamin D and calcium balance may therefore contribute to altered bone metabolism and reduced bone mineral density[11].

Despite abundant sunlight, hypovitaminosis D is widely prevalent in many populations, including women in Bangladesh. Lifestyle factors, limited sun exposure, dietary insufficiency, and cultural practices may contribute to this high prevalence[12]. Previous studies have reported inconsistent findings regarding the association between serum vitamin D levels and bone mineral density, with some demonstrating positive correlations and others reporting weak or no associations[13]. As a result, the relationship between vitamin D status and bone mineral density remains controversial, particularly among adult females in Bangladesh, where relevant data are limited. The aim of the study to assess serum vitamin D levels and to evaluate their association with bone mineral density among adult females of Bangladesh.

2. Methods and materials

2.1. Study Design and Setting

This cross-sectional study was conducted in the Department of Physiology, Dhaka Medical College, Dhaka, Bangladesh, over a one-year period from January 2019 to December 2019. The study population consisted of adult Bangladeshi females residing in different areas of Dhaka city.

2.2. Study Population and Sample Size

A total of 70 adult females aged between 18 and 44 years were enrolled using purposive sampling based on predefined inclusion and exclusion criteria. Participants were recruited from various locations within Dhaka city. The final analysis included subjects with normal bone mineral density, while individuals identified with osteopenia during screening were excluded.

2.3. Eligibility Criteria

Eligible participants were adult Bangladeshi females aged 18–44 years with normal body mass index (18.5–24.9 kg/m^2) and normal bone mineral density (BMD T-score > −1). Only subjects with normal biochemical parameters, including serum parathyroid hormone, calcium, phosphate, albumin, creatinine, SGPT, and fasting blood glucose levels, were included. Participants were excluded if they had any known hepatic, renal, gastrointestinal, thyroid, parathyroid, or metabolic bone disorders, malignancy, or a history of prolonged use of steroids or anti-osteoporotic medications. Pregnant or lactating women were also excluded.

2.4. Study Procedure

Potential participants were contacted either in person or by telephone and were informed about the objectives, procedures, and benefits of the study. After obtaining consent, detailed personal, dietary, medical, and drug histories were recorded using a structured questionnaire. Socioeconomic status was assessed using a modified Kuppuswamy scale. Eligible subjects were referred to the Institute of Nuclear Medicine and Allied Sciences (INMAS), Dhaka Medical College, for bone mineral density measurement. Following BMD assessment, participants were advised to provide blood samples for biochemical analysis.

2.5. Bone Mineral Density Measurement

Bone mineral density was measured at the lumbar spine and femoral neck using dual-energy X-ray absorptiometry (DEXA) with a QDR-2000 densitometer (Hologic, USA) at INMAS, Dhaka Medical College. Bone status was classified according to World Health Organization criteria as normal (T-score > −1), osteopenia (T-score −1 to −2.5), or osteoporosis (T-score < −2.5).

2.6. Blood Sample Collection and Biochemical Analysis

Under aseptic conditions, 5 mL of venous blood was collected from the antecubital vein of each participant. Part of the sample was used for fasting blood glucose estimation, and the remaining serum was separated by centrifugation for biochemical analyses. Serum vitamin D and parathyroid hormone levels were measured using chemiluminescence immunoassay methods. Serum calcium, phosphate, albumin, creatinine, fasting blood glucose, and SGPT were analyzed using automated biochemistry analyzers following standard laboratory procedures.

2.7. Anthropometric and Clinical Measurements

Height and weight were measured using an ultrasonic height and weight machine with participants wearing light clothing and no footwear. Body mass index was calculated as weight in kilograms divided by height in meters squared. Pulse rate and blood pressure were measured in the sitting position using standard clinical methods after adequate rest.

2.8. Statistical Analysis

Data were analyzed using the Statistical Package for Social Sciences (SPSS) version 26.0. Continuous variables were expressed as mean ± standard deviation. Group comparisons were performed using Chi-square test and analysis of variance (ANOVA). Pearson's correlation coefficient and regression analyses were conducted to evaluate the association between serum vitamin D levels and bone mineral density. A p-value of less than 0.05 was considered statistically significant.

3. Results

A total of 70 healthy adult women from Dhaka city were included in the study. The general characteristics of the study participants are presented in Table 1. The age of the participants ranged from 20 to 43 years, with a mean (±SD) age of 31.0 ± 5.20 years. The body mass index ranged from 18.5 to 24.8 kg/m^2, and the mean (±SD) BMI was 22.1 ± 1.93 kg/m^2. The systolic blood pressure of the participants ranged from 100 to 130 mmHg, with a mean (±SD) value of 107.38 ± 9.40 mmHg. The diastolic blood pressure ranged from 60 to 80 mmHg, and the mean (±SD) diastolic pressure was 70.61 ± 7.63 mmHg.

Table 1 General Characteristics of the Study Subjects (N = 70)

Parameter	Mean ± SD (Range)
Age (years)	31.0 ± 5.20 (20.0–43.0)
Body Mass Index (kg/m^2)	22.1 ± 1.93 (18.5–24.8)
Systolic Blood Pressure (mmHg)	107.38 ± 9.40
Diastolic Blood Pressure (mmHg)	70.61 ± 7.63

Baseline biochemical parameters of the study subjects are presented in Table 2 The mean (±SD) serum parathyroid hormone level was 38.59 ± 9.47 pg/mL. The mean (±SD) serum calcium and phosphate levels were 8.96 ± 0.43 mg/dL and 3.27 ± 0.56 mg/dL, respectively. Serum albumin showed a mean (±SD) value of 4.47 ± 0.35 g/dL. The mean (±SD)

fasting blood glucose level was 4.90 ± 0.45 mmol/L. Liver and renal function markers remained within normal limits, with mean (±SD) SGPT and serum creatinine levels of 30.43 ± 6.45 U/L and 0.69 ± 0.17 mg/dL, respectively.

Table 2 Baseline Biochemical Parameters of the Study Subjects (N = 70)

Parameter	**Mean ± SD (Range)**
Serum PTH (pg/mL)	38.59 ± 9.47 (14.1–56.22)
Serum Calcium (mg/dL)	8.96 ± 0.43 (8.25–9.82)
Serum Phosphate (mg/dL)	3.27 ± 0.56 (2.47–4.86)
Serum Albumin (g/dL)	4.67 ± 0.35 (3.10–5.13)
Fasting Blood Glucose (mmol/L)	4.90 ± 0.45 (3.94–5.93)
Serum Creatinine (mg/dL)	0.69 ± 0.17 (0.4–1.1)
SGPT (U/L)	30.43 ± 6.45 (10–39)

Serum vitamin D status of the study subjects is presented in Table II. The mean (±SD) serum vitamin D level of the total study population was 22.13 ± 2.59 ng/mL, with values ranging from 17.58 to 31.24 ng/mL. Based on standard classification, vitamin D sufficiency was observed in only 2.9% of participants, whereas insufficiency and deficiency were found in 75.7% and 21.4% of the subjects, respectively. The majority of the study subjects belonged to the vitamin D insufficiency group. A statistically significant difference in mean serum vitamin D levels was observed among the groups (p = 0.013).

Table 3 Serum Vitamin D Status of the Study Subjects (N = 70)

Vitamin D Status	**N (%)**	**Serum Vitamin D Level (ng/mL) Mean ± SD (Range)**	**p-value**
Sufficient	2 (2.9%)	30.98 ± 0.37 (30.72–31.24)	
Insufficient	53 (75.7%)	22.56 ± 1.89 (20.10–28.26)	0.013*
Deficient	15 (21.4%)	19.45 ± 0.65(17.58–19.99)	
Total	70 (100%)	22.13 ± 2.59	

Bone mineral density according to serum vitamin D status is shown in Table 4. The mean lumbar spine and femoral neck T-scores did not differ significantly among subjects with sufficient, insufficient, and deficient vitamin D levels. No statistically significant association was observed between serum vitamin D status and BMD at either the lumbar spine (p = 0.136) or femoral neck (p = 0.550).

Table 4 Bone Mineral Density (T-score) of the Study Subjects According to Serum Vitamin D Status (N = 70)

Vitamin D Status	Lumbar Spine T-score (Mean ± SD, Range)	Femoral Neck T-score (Mean ± SD, Range)
Sufficient (n = 2)	−0.80 ± 0.28 (−1.0 to −0.6)	−0.25 ± 0.07 (−0.3 to −0.2)
Insufficient (n = 53)	−0.09 ± 0.81 (−1.0 to 1.4)	−0.01 ± 0.78 (−1.0 to 1.4)
Deficient (n = 15)	0.28 ± 0.91 (−1.0 to 1.5)	−0.23 ± 0.85 (−0.9 to 1.9)
p-value	0.136 (ns)	0.550 (ns)

ns = not significant

The association between serum vitamin D levels and bone mineral density T-scores is presented in Table 5. Serum vitamin D showed a weak negative correlation with lumbar spine BMD T-score (r = −0.073) and a weak positive correlation with femoral neck BMD T-score (r = 0.037); however, neither association was statistically significant (p > 0.05).

Table 5 Correlation Between Serum Vitamin D Level and Bone Mineral Density T-score (N = 70)

Parameter	r value	p value
BMD T-score (Lumbar Spine)	−0.073	0.548 (ns)
BMD T-score (Femoral Neck)	0.037	0.760 (ns)

ns = not significant

Serum vitamin D level showed a weak negative correlation with bone mineral density T-score at the lumbar spine (Figure 1) and a weak positive correlation with femoral neck T-score (Figure 2).

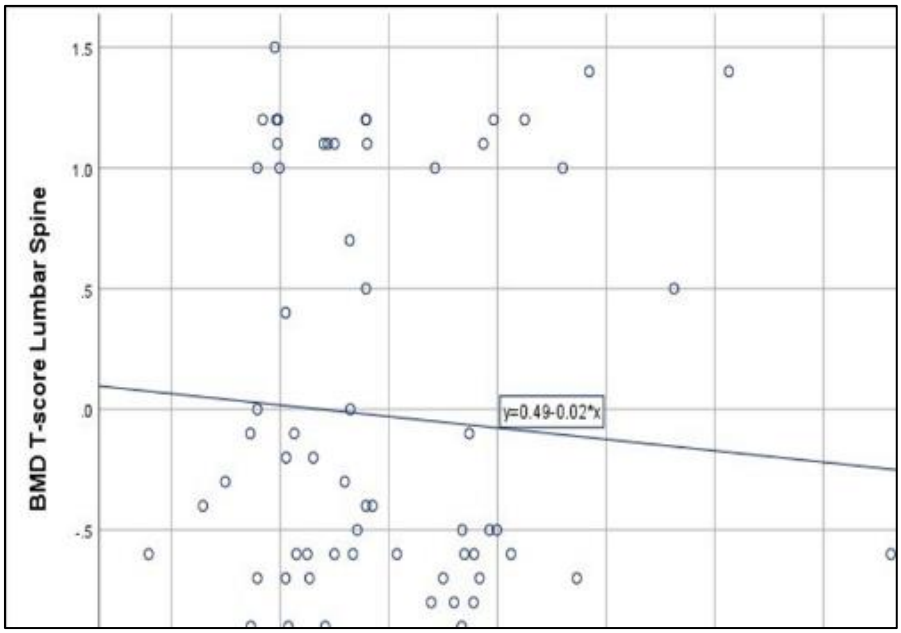

Figure 1 Scatter diagram showing the association of serum vitamin D level with Bone mineral density T score (Lumbar spine) (N=70)

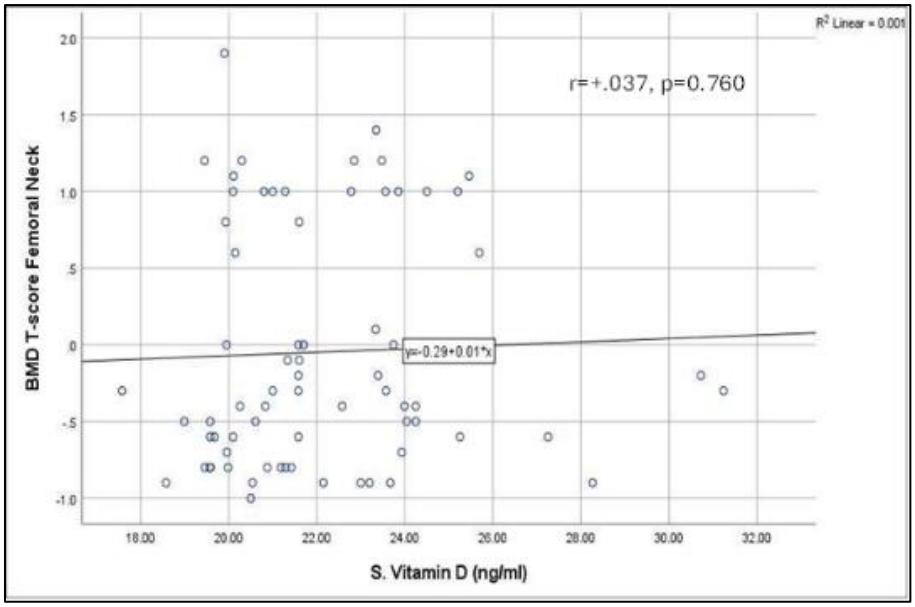

Figure 2 Scatter diagram showing the association of serum vitamin D level with Bone mineral density T score (Femoral neck) (N=70)

Linear regression analysis showed that bone mineral density T-scores at both the lumbar spine and femoral neck were not significantly associated with serum vitamin D levels. The regression coefficients were small and statistically non-significant, with confidence intervals crossing zero (Table 6).

Table 6 Linear regression of Bone mineral density T score with serum vitamin D level

Predictor (BMD T-score)	Unstandardized Coefficient (B)	Standard Error	Standardized Coefficient (β)	p-value	95% CI for B (Lower–Upper)
Lumbar spine	−0.261	0.384	−0.085	0.498	−1.028 to 0.505
Femoral neck	0.184	0.414	0.055	0.659	−0.643 to 1.011

Coefficients[a] a. Dependent Variable: Serum vitamin D (ng/ml)

4. Discussion

The age of the study participants ranged from 20 to 43 years, with a mean age of 31.0 ± 5.20 years. All subjects had normal BMI and blood pressure values and belonged to a middle-class socioeconomic background. Analysis revealed no significant association between serum vitamin D levels and bone mineral density in this age group. This finding is consistent with previous studies conducted among adult females in similar age ranges, which also reported no significant correlation between vitamin D status and BMD in healthy premenopausal women[14]. In contrast, studies involving broader age ranges or elderly populations have demonstrated a positive association between vitamin D levels and BMD, particularly among older adults, suggesting that age-related factors may influence this relationship[15]. The discrepancy between findings may be attributed to differences in age distribution, hormonal status, and confounding factors related to aging.

The mean BMI of the participants was within the normal range, indicating adequate nutritional status. Similar observations have been reported in studies involving young adult females with normal BMI[16]. However, studies conducted among populations with lower socioeconomic status have reported an association between vitamin D deficiency and reduced bone mineral density, possibly due to malnutrition and low dietary intake[17]. These differences highlight the potential influence of nutritional status and socioeconomic conditions on bone health.

A high prevalence of hypovitaminosis D was observed in the present study, with the majority of participants exhibiting vitamin D insufficiency and a smaller proportion showing deficiency. Despite Bangladesh being located in a region with abundant sunlight throughout the year, vitamin D deficiency remains common. This paradox may be explained by

lifestyle factors such as limited sun exposure, clothing habits, reduced outdoor physical activity, dietary insufficiency, environmental pollution, and individual variability in cutaneous vitamin D synthesis[18,19]. Similar high prevalence rates of hypovitaminosis D have been reported among Bangladeshi women and other populations worldwide[20,21].

Although serum vitamin D levels were low, serum parathyroid hormone, calcium, phosphate, albumin, liver enzymes, and renal function markers remained within normal ranges. Physiologically, low vitamin D levels are expected to increase parathyroid hormone secretion through a negative feedback mechanism. However, normal PTH levels observed in this study suggest that additional regulatory factors, such as calcium homeostasis, renal function, age, ethnicity, and genetic variability, may modulate parathyroid hormone response[22,23]. Similar findings have been reported in studies conducted in different populations[24,25].

In contrast, some studies have demonstrated elevated parathyroid hormone levels in individuals with vitamin D deficiency[26]. Differences in assay methods used for vitamin D and PTH estimation may partly explain these inconsistencies. Advanced analytical techniques such as liquid chromatography–mass spectrometry have been reported to provide more accurate measurements compared to immunoassay-based methods[27].

Bone mineral density values at both the lumbar spine and femoral neck in this study were within normal limits. This contrasts with findings from studies involving older populations or individuals presenting with musculoskeletal complaints, where a higher prevalence of low bone mass has been observed[28]. Age-related bone loss and selection of symptomatic individuals may account for this variation.

The present study did not demonstrate any significant correlation between serum vitamin D levels and bone mineral density at either the lumbar spine or femoral neck. Similar findings have been reported in studies conducted among healthy women in Bangladesh and other countries, where vitamin D deficiency coexisted with normal bone mineral density without a direct causal relationship[29-30]. Possible explanations include the relatively young age of the participants, small sample size, normal baseline bone mass, and ethnic or genetic differences influencing vitamin D metabolism.

Emerging evidence suggests that South Asian populations tend to have lower serum vitamin D levels compared to Western populations, possibly due to genetic polymorphisms affecting vitamin D transport and metabolism[31,32]. These population-specific variations indicate that vitamin D reference ranges derived from Western populations may not be fully applicable to Asian women.

5. Conclusion

The present study demonstrates a high prevalence of vitamin D insufficiency and deficiency among healthy adult Bangladeshi women, without a significant association with bone mineral density. These findings suggest that low serum vitamin D levels may not adversely affect bone mineral density in young adult females. Further large-scale and longitudinal studies incorporating genetic analysis are warranted to establish population-specific reference ranges and to clarify the role of vitamin D in bone health among Bangladeshi women.

Limitations

Despite careful methodological planning and execution, this study has several limitations. The sample was selected using purposive sampling, which may limit the generalizability of the findings. Participants were recruited exclusively from a middle socioeconomic background within Dhaka city, and therefore the results may not represent individuals from other socioeconomic groups or rural areas of Bangladesh. Additionally, genetic analyses to assess polymorphisms related to vitamin D metabolism or parathyroid hormone regulation could not be performed due to time and financial constraints.

Recommendations

To obtain more conclusive and generalizable results, further studies are recommended. Future research should include a larger and more diverse sample population encompassing different socioeconomic and geographic backgrounds. Genetic studies focusing on vitamin D receptor and parathyroid hormone-related gene polymorphisms among Bangladeshi women are warranted. Furthermore, population-specific cutoff values for vitamin D sufficiency should be established to better assess associated risk factors and guide appropriate public health interventions.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this study.

Statement of ethical approval

The study protocol was approved by the Research Review Committee of the Department of Physiology and the Ethical Review Committee of Dhaka Medical College, Dhaka (MEU-DMC/ECC/2019/298). Written informed consent was obtained from all participants prior to enrolment, and confidentiality of participant information was strictly maintained throughout the study.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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