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The Association between 25-Hydroxyvitamin D and Metabolic Syndrome Components in Bangladeshi Adults.

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KEYWORDS

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ABSTRACT:

Background: In Bangladesh, the prevalence of metabolic syndrome is increasing day by day, and it is an important cause of cardiovascular disease and diabetes. The widespread occurrence of vitamin D deficiency has highlighted its potential role in increasing the risk of metabolic syndrome.

Objective: The purpose of this study was to examine how vitamin D status influences the components of metabolic syndrome.

Methods: This cross-sectional study included 80 adults, with both genders represented, most of whom were from urban, middle-class backgrounds. Clinical, biochemical, and anthropometric data were collected, including serum 25-hydroxyvitamin D levels, lipid profiles, glycemic markers, and measures of insulin resistance. The frequency of metabolic syndrome components was determined using chi-square tests, while Pearson's correlation was applied to assess associations with vitamin D status.

Results: The frequency of vitamin D deficiency was 92.1%, while only 0.7% of participants had sufficient levels. Increased waist circumference and low HDL cholesterol levels were the most frequently observed metabolic disturbances. A significant association was found between vitamin D deficiency and low HDL cholesterol ($p = 0.016$), whereas no meaningful associations were observed with high blood glucose, elevated blood pressure, or elevated triglycerides. Additionally, vitamin D levels showed a positive correlation with age ($r = 0.274$, $p = 0.014$), indicating slightly higher levels among older participants.

Conclusion: The study found that vitamin D deficiency is more prevalent among overweight and obese adults residing in urban Bangladesh. While vitamin D deficiency was associated with low HDL cholesterol, it did not show a strong association with the other metabolic components.

Introduction: As a public health concern, metabolic syndrome (MS) has gained more attention in recent years due to its rising incidence.1 In conjunction with global trends, the incidence of MS in Bangladesh has consistently increased throughout the years, along with the advancements in industrialization and globalization.[2] If the risk factors for metabolic syndrome in our population are identified and preventative actions are taken, consequences with significant morbidity and mortality could be avoided.[3] Beyond its classic roles in calcium homeostasis and bone mineralization, vitamin D has attracted attention for its potential impact on metabolic health.[4] Vitamin D receptors are present in multiple tissues, including pancreatic β-cells, adipose

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tissue, and vascular endothelium, indicating that vitamin D may influence insulin secretion, inflammatory processes, and lipid metabolism. [5]

Even though there is enough sunlight in many places, deficiencies are nevertheless widespread and impact around one billion people globally.[6] A complicated relationship between lifestyle, skin pigmentation, and limited sun exposure contributes to the exceptionally high rates of 70–75% observed in South Asia and the Middle East, where the problem is particularly severe.[7,8] Numerous observational and longitudinal studies have examined the role of insufficient vitamin D in the development of metabolic syndrome. Many of these studies demonstrated an inverse relation between lower serum 25-hydroxyvitamin D concentrations and insulin resistance, obesity, and dyslipidemia. [9-11] Considering these inconsistencies, it is essential to evaluate the relationship between 25-hydroxyvitamin D levels and components of MS in particular populations. Both vitamin D deficiency and metabolic syndrome are highly prevalent in Bangladesh.[2,12,13] So such an investigation is particularly relevant to evaluating this relationship in the local context. The results would provide information specific to regional risk profiles, lifestyles, and health system priorities, enabling medical professionals to address the issue more effectively.

Methods

Study Design and Participants: This cross-sectional study was carried out over one year at the Endocrinology outpatient clinic of Bangladesh Medical University, Dhaka, including 80 persons (ages 18–45), categorized as overweight (BMI 23.0–24.9 kg/m²) or obese (BMI ≥25 kg/m²) based on WHO Asian criteria. Exclusion criteria included patients with liver or renal disease, acute illness, pregnancy or lactation, or those who were currently taking vitamin D and calcium or had received them within the previous 120 days. Additionally, patients with secondary causes of obesity, such as hypothyroidism or Cushing syndrome, and those who had a history of taking drugs that cause glucose intolerance and/or weight gain (e.g., glucocorticoids, antipsychotics) were excluded.

Sample size: Here, the sample size has been determined by a formula used for cross-sectional studies $=Z^2pq / d^2$, p = Prevalence of metabolic syndrome (30%) = 0.30. [2]

Biochemical Analysis: All laboratory variables were analyzed at the Department of Biochemistry of the BMU. **Vitamin D:** The ARCHITECT 25-OH vitamin D test, a chemiluminescent microparticle immunoassay (CMIA), was used to measure 25-hydroxyvitamin D (25-OH vitamin D) levels. **Insulin:** The ARCHITECT insulin test is a chemiluminescent microparticle immunoassay (CMIA) that quantitatively measures human insulin. **Glucose:** Plasma glucose was measured using an automated analyzer, Atellica CH, with glucose oxidase (GluO) technology. Precision of plasma glucose assay: repeatable coefficient of variation (CV): 0.3%. **HbA1c:** The Sebia Capillary HbA1c assay was utilized for measuring HbA1c levels—within-run repeatability (CV%): 1.4%; between-run reproducibility (CV%): 1.2%. **Lipid Profile:** comprising total cholesterol (TC), triglycerides (TG), and high-density lipoprotein cholesterol (HDL-C) was assessed using the automated analyzer Architect Plus ci8200. Low-density lipoprotein cholesterol (LDL-C) was computed using the Friedewald equation: LDL-C = TC – HDL-C – (TG/5).

Vitamin D status: 25(OH) D cutoffs to define deficiency (≤20 ng/ml), insufficiency (21-29 ng/ml), and sufficient (≥30) were used according to Endocrine Society (USA) criteria. [14]

Metabolic syndrome: Metabolic syndrome was determined according to the International Diabetes Federation (IDF) criteria. [15]

Waist circumference (WC): According to the International Diabetes Federation's criteria, the normal WC values for the South Asian population are as follows: men, <90 cm; women, <80 cm.

Table I: Glycemia categorization

Parameters	Fasting plasma glucose (mmol/L)	Two-hour Plasma glucose(mmol/L) during an 75-gm OGTT	HbA1C(%)

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Overt diabetes mellitus	≥7	≥11.1	≥6.5
Impaired fasting glucose	5.6 to 6.9	≤7.7	5.7 to 6.4.
Normoglycemia	≤5.5	≤7.7	≤5.6

(American Diabetes Association 2021)[16]

Insulin Resistance (IR): The HOMA-IR cut-off is 2.6.[17.] The Homeostasis model of insulin resistance measures IR,

$$(\text{HOMA-IR}) = \frac{\text{Fasting insulin } (\mu U/ml) \times \text{fasting glucose (mmol/l)}}{22.5}$$

Socio-economic status was determined arbitrarily based on monthly income. Specifically, an income of less than 30,000 taka/month was considered lower, a monthly income between 30,000 and 100,000 taka was considered middle, and an income exceeding 100,000 taka was considered higher socio-economic status.

Physical activity: According to the National STEPS Survey for Non-communicable Diseases Risk Factors in Bangladesh 2018.[18] Expressed in minutes of physical activity throughout the week, walking for less than 15 minutes at least five days a week is considered low physical activity, walking 15 to 30 minutes is considered moderate, and walking more than 30 minutes per day, at least 5 days a week, is considered high physical activity**.**

Area of Residence: Follow the administrative classification of the Bangladesh Bureau of Statistics.[19] If the participant lives in a city, corporation, or municipality, it is considered an urban area. If the participant lives in a village within a union parishad, the area is considered rural.

Occupation: Classified according to the Bangladesh Bureau of Statistics (BBS), Statistics and Informatics Division, Ministry of Planning. [19]

Statistical Analysis: The data were loaded into SPSS (version 22.0) and analyzed using descriptive and inferential statistics. Continuous data were given as mean ± SD or median (IQR), while categorical variables were reported as frequencies and percentages. The Shapiro-Wilk test assessed normality. Pearson's Chi-square test was used to examine relationships between categorical variables. Pearson's correlation coefficient was used to investigate the relationship between serum vitamin D and components of metabolic syndrome, including triglycerides, HDL-C, and HOMA-IR. A p-value < 0.05 was considered statistically significant.

Results: Among the 80 participants, 61.3% were aged 30 years or older, 78.8% resided in urban areas, 53.8% were of middle-income status, and 51.3% reported low physical activity; the gender distribution was nearly equal. Most of the participants were in the middle-aged group and belonged to the moderate physical activity group (Table II)

Insulin resistance (HOMA-IR ≥ 2.6) was present in 62.5% of the participants. Glycemic status showed 42.5% with normoglycemia, 33.8% with impaired fasting glucose, and 23.8% with diabetes mellitus.

Metabolic syndrome components did not differ significantly by vitamin D status, except for HDL cholesterol, which was lower in individuals with vitamin D deficiency ($p = 0.016$). Elevated waist circumference was common, while triglycerides, blood pressure, fasting glucose, HbA1c, insulin, and HOMA-IR showed no significant associations with vitamin D levels.

Metabolic syndrome was strongly associated with obesity ($p < 0.001$), glycemic status ($p = 0.0017$), blood pressure ($p = 0.0008$), triglycerides ($p < 0.001$), and HDL cholesterol ($p = 0.0402$). Vitamin D levels approached significance ($p=0.0589$), suggesting a possible link to metabolic syndrome.

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Table II: Socio-demographic characteristics of the study population (N = 80)

Characteristics		Frequency (%)
Age Group		
	Less than 30 years	31 (38.75)
	30 years and above	49 (61.25)
Region		
	Rural	17 (21.25)
	Urban	63 (78.75)
Gender		
	Female	39 (48.75)
	Male	41 (51.25)
Occupation		
	Managerial and professional	22 (27.5)
	Manual	18 (22.5)
	Nonmanual	40 (50)
Socio-economic status		
	Higher	28 (35)
	Lower	9 (11.25)
	Middle	43 (53.75)
Physical Activity		
	High	5 (6.25)
	Low	41 (51.25)
	Moderate	34 (42.5)

Within parentheses are percentage over the row total

Table III: Clinical and biochemical characteristics of the study population

Characteristics		Frequency (%)
BMI		
	Obese	72 (90.00)
	Overweight	8 (10.00)
Vitamin D		
	Deficiency (< 20 ng/ml)	69 (86.25)
	Insufficiency (20–29.9 ng/ml)	10 (12.50)

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	Sufficiency (≥ 30 ng/ml)	1 (1.25)
Triglyceride (mg/dL)		
	<150	26 (32.50)
	≥150	54 (67.50)
HDL cholesterol (mg/dL)		
	Men < 40 & women < 50	57 (71.25)
	Men ≥ 40 & women ≥ 50	23 (28.75)

Within parentheses are percentage over the row total

Insulin Resistance Status of the Study Population

In the study population, insulin resistance, defined as HOMA-IR ≥ 2.6, was present in 50 participants (62.5% of the sample). In contrast, 30 participants (37.5%) had HOMA-IR values below 2.6, indicating no insulin resistance (Fig. 1).

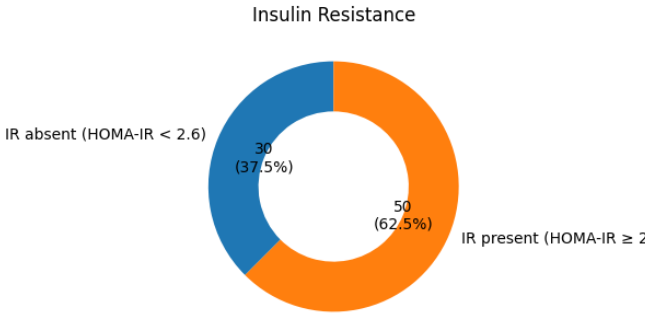

Fig. I Insulin Resistance Status of the Study Population

Glycemic Status of the Study Population

The glycemic status distribution demonstrates that 34 people (42.5%) had normoglycemia, accounting for the majority of the sample. Twenty-seven patients (33.8%) had impaired fasting glucose, while 19 (23.8%) had overt diabetes mellitus (Fig. 2).

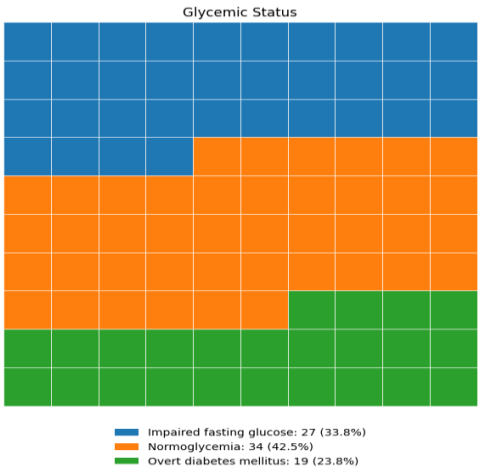

Fig II. Glycemic Status of the Study Population

Table IV: Association Between Vitamin D Levels and Components of Metabolic Syndrome

Characteristic	Total	Deficiency (<20 ng/ml) n (%)	Insufficiency (20–29.9 ng/ml) n (%)	Sufficiency (≥30 ng/ml) n (%)	p value*
Waist circumference (cm)					
Men ≥90	41	34 (49.28)	7 (70.00)	0 (0.00)	0.277
Women ≥80	39	35 (50.72)	3 (30.00)	1 (100.00)	
Triglyceride (mg/dL)					
<150	26	21 (30.43)	5 (50.00)	0 (0.00)	0.366
≥150	54	48 (69.57)	5 (50.00)	1 (100.00)	

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HDL cholesterol (mg/dL)					
Men <40 & Women <50	57	53 (76.81)	4 (40.00)	0 (0.00)	0.016
Men ≥40 & Women ≥50	23	16 (23.19)	6 (60.00)	1 (100.00)	
Blood pressure					
Normotensive (<130/85)	22	19 (27.54)	3 (30.00)	0 (0.00)	0.814
Hypertensive (≥130/85)	58	50 (72.46)	7 (70.00)	1 (100.00)	
Fasting glucose (mmol/L)					
<5.6	34	30 (43.48)	4 (40.00)	0 (0.00)	0.673
≥5.6	46	39 (56.52)	6 (60.00)	1 (100.00)	
HbA1c (%)					
Diabetes (≥6.5%)	27	21 (30.43)	5 (50.00)	1 (100.00)	0.449
Normal (<5.7%)	16	15 (21.74)	1 (10.00)	0 (0.00)	
Prediabetes (5.7–6.4%)	37	33 (47.83)	4 (40.00)	0 (0.00)	
Fasting Insulin					
High (≥29.46)	20	17 (24.64)	3 (30.00)	0 (0.00)	0.79
Lower (<29.46)	60	52 (75.36)	7 (70.00)	1 (100.00)	
Insulin Resistance (HOMA-IR)					
IR absent (<2.6)	30	27 (39.13)	2 (20.00)	1 (100.00)	0.217
IR present (≥2.6)	50	42 (60.87)	8 (80.00)	0 (0.00)	

* p-value obtained from chi-square test

Table V: Association between Metabolic syndrome & other cofactors

Parameters	**Metabolic disorders**	**Metabolic disorders**	**p-value***
	Present	Absent	
Vitamin D status			
Deficiency (< 20 ng/ml)	58 (47.54)	71 (52.27)	0.0589
Insufficiency (20-29.9 ng/ml)	8 (6.56)	2 (1.47)	
Sufficiency (≥ 30 ng/ml)	1 (0.82)	0 (0.00)	

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Age of respondent			
Less than 30 years	26 (21.31)	5 (3.68)	0.999
30 years and above	41 (33.61)	8 (5.88)	
Region			
Urban	50 (40.98)	13 (9.56)	0.0937
Rural	17 (13.93)	0 (0.00)	
Gender			
Male	33 (27.05)	8 (5.88)	0.6116
Female	34 (27.87)	5 (3.68)	
Physical activity			
Low	32 (26.23)	9 (6.62)	0.2935
Moderate	30 (24.59)	4 (2.94)	
High	5 (4.10)	0 (0.00)	
BMI			
Overweight	7 (5.74)	1 (0.74)	0.999
Obese	60 (49.18)	12 (8.82)	
Glycemic status			
Normoglycemia	21 (17.21)	0 (0.00)	0.0017
Impaired fasting glucose	34 (27.87)	5 (3.68)	
Overt diabetes mellitus	12 (9.84)	8 (5.88)	
Blood Pressure			
Normotensive (<130/85)	13 (10.66)	9 (6.62)	0.0008
Hypertensive (≥130/85)	54 (44.26)	4 (2.94)	
Total cholesterol (mg/dl)			
<200	48 (39.34)	9 (6.62)	0.999
≥200	19 (15.57)	4 (2.94)	
High density lipoprotein (mg/dl)			
Men < 40 & women < 50	51 (41.80)	66 (48.18)	0.0402
Men ≥ 40 & women ≥ 50	16 (13.11)	7 (5.11)	
Low-density lipoprotein (mg/dl)			
<130	52 (42.62)	9 (6.62)	0.7689
≥130	15 (12.30)	4 (2.94)	

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Triglycerides (mg/dl)			
<150	13 (10.66)	73 (53.29)	0.000
≥150	54 (44.26)	0 (0.00)	

* p-value obtained from the chi-square test

Discussion: Serum vitamin D levels and components of metabolic syndrome are examined in this study to assess their potential effects on metabolic health in high-risk individuals. Here, one of the most important observations was a high frequency of vitamin D deficiency. About 80% of individuals failed to meet the vitamin D sufficiency criteria. Only one individual had an adequate vitamin D level. These observations indicate regional patterns previously documented in South Asia and the Middle East, where insufficiency is prevalent despite adequate solar exposure.[7,8] Limited outdoor activities, urban lifestyle, food habits, and vitamin D sequestration in adipose tissue among obese people are all possible contributing factors to this prevalent deficiency.[20] The clustering of metabolic risk factors was also prominent. Most participants had lower HDL cholesterol and increased waist circumference. Insulin resistance was common, and almost 60% of participants had impaired fasting glucose or overt diabetes. These patterns highlight the emerging public health issue brought about by metabolic syndrome in urban populations of Bangladesh. [21,22]

The study results indicated that although all individuals met the criterion for increased waist circumference, there was no significant difference in blood pressure, triglyceride levels, or fasting glucose across vitamin D categories. In correlation analyses, vitamin D status was significantly associated with HDL cholesterol: individuals with vitamin D deficiency were more likely to have lower HDL levels. This observation is consistent with other epidemiological studies, indicating that low vitamin D levels may negatively affect lipid metabolism, either directly through hepatic lipid regulation or through inflammatory mechanisms.[2,23,24] Nevertheless, no substantial correlations were seen between vitamin D levels and other factors, including blood pressure, serum lipids, or plasma glucose level. While vitamin D levels approached statistical significance in relation to the overall frequency of metabolic syndrome, the association remained inconclusive. This indicates a potential, albeit not conclusive, association between vitamin D insufficiency and metabolic syndrome within these individuals. The observations of this study are consistent with those of other studies. [25,26] Impaired plasma glucose, obesity, raised blood pressure, and dyslipidemia (defined by low HDL and high triglycerides) were all substantially correlated with metabolic syndrome, underscoring their central role in its pathogenesis.

Vitamin D levels correlated positively with age, with older subjects demonstrating substantially higher levels at relatively younger ages. This observation contradicts previous investigations, which report declining vitamin D levels with ageing, sometimes attributable to reduced cutaneous synthesis with advancing age. [27,28,29] This disparity may indicate variations in sun exposure patterns or vitamin D supplementation among older subjects, supporting additional research. No substantial relationships were identified between vitamin D levels and BMI, waist circumference, blood pressure, plasma glucose, serum insulin, HOMA-IR, HbA1c, or lipid profile. Although some factors indicated weak associations (e.g., with HDL cholesterol and triglycerides), they were not deemed statistically significant. Several studies have shown no strong link between vitamin D levels and metabolic parameters, even after adjusting for other factors that might have affected the results.[30,31] Vitamin D is believed to impact metabolic health by affecting insulin production and sensitivity, inflammation, and lipid metabolism.[32] The clinical impact of vitamin D supplementation on metabolic outcomes is contentious, with some research indicating a beneficial effect, while others have shown no meaningful effect.[33-35] The scientific data on vitamin D and metabolic syndrome is inconsistent; while several research indicate an adverse relationship between vitamin D status and metabolic syndrome or its components, others have found no meaningful relationship or effect of supplementation. [13, 35-37] This variation could be due to variations in methodology, different populations, or even characteristics that influence both, such sedentary lifestyles, unhealthy diets, or obesity.[38]

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This study's strengths are that it focuses on metabolic syndrome and vitamin D deficiency in the target group and provides valuable information on these topics, especially the higher frequency of vitamin D deficiency. The cross-sectional nature of this study is another limitation. Although this study has some flaws, it shows that the link between vitamin D and metabolic health warrants further research on a larger scale, with a broader range of the population throughout the country.

Conclusion: The primary finding of this cross-sectional study is a higher prevalence of vitamin D deficiency among people with metabolic syndrome. While vitamin D deficiency was substantially associated with low HDL cholesterol, it was not significantly associated with the other metabolic syndrome factors. These findings add to our expanding understanding of vitamin D's role in metabolic health and underscore the importance of large-scale, longitudinal research to clarify these associations and guide our day-to-day clinical practice.

Ethical Approval and Consent to Participate: This study was approved by the Institutional Review Board (IRB) of BMU, Reg. No. BSMMU/2021/12942). Informed written consent was obtained from each of the participants.

Conflict of interest

The authors declare that they have no conflicts of interest.

Acknowledgements

Disclosure

The authors declare that they have no conflicts of interest.

Financial Disclosure

Data Availability

Data supporting this study are available from the corresponding author upon reasonable request.

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