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Original Article

Association Between Vitamin D Deficiency and Metabolic Syndrome

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Abstract-

Background: Vitamin D deficiency is a global public health concern and has been increasingly associated with various metabolic disorders. Metabolic syndrome (MetS) is a cluster of risk factors including central obesity, hypertension, dyslipidemia, and impaired glucose metabolism that significantly increases the risk of cardiovascular disease and type 2 diabetes mellitus. ***Objective:*** To evaluate the association between vitamin D deficiency and metabolic syndrome among adults. ***Materials and Methods:*** A cross-sectional study was conducted among 200 adults aged 20–60 years attending a tertiary care hospital. Serum 25-hydroxyvitamin D [25(OH)D] levels were measured and participants were categorized as vitamin D deficient (<20 ng/mL), insufficient (20–29 ng/mL), or sufficient (≥30 ng/mL). Metabolic syndrome was diagnosed according to the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) criteria. Anthropometric measurements, blood pressure, fasting blood glucose, and lipid profile were recorded. Statistical analysis was performed using chi-square test and logistic regression. A p-value <0.05 was considered statistically significant. ***Results***: Among 200 participants, 120 (60%) were vitamin D deficient. Metabolic syndrome was present in 82 (41%) participants. The prevalence of metabolic syndrome was significantly higher among vitamin D-deficient individuals (58.3%) compared to those with sufficient vitamin D levels (18.8%) (p<0.001). Vitamin D deficiency was significantly associated with increased waist circumference, elevated fasting blood glucose, hypertriglyceridemia, and hypertension. ***Conclusion***: Vitamin D deficiency was significantly associated with metabolic syndrome and its individual components. Regular screening and correction of vitamin D deficiency may contribute to reducing the burden of metabolic syndrome and related cardiovascular complications.

Keywords: *Vitamin D deficiency, Metabolic syndrome, Obesity, Dyslipidemia, Insulin resistance, Cardiovascular risk.*

INTRODUCTION

Vitamin D is a fat-soluble vitamin that plays a critical role in calcium and phosphorus homeostasis, skeletal health, and immune regulation. In recent years, growing evidence has suggested that vitamin D may also influence several non-skeletal conditions, including cardiovascular diseases, diabetes mellitus, obesity, and metabolic syndrome (1). Vitamin D is primarily synthesized in the skin upon exposure to ultraviolet B radiation, while a smaller proportion is obtained through dietary intake and supplementation (2).

Vitamin D deficiency has emerged as a global health problem affecting approximately one billion individuals worldwide (3). The prevalence is particularly high in developing countries due to inadequate sunlight exposure, urbanization, sedentary lifestyle, dietary insufficiency, and increasing obesity rates (4). In India, despite abundant sunlight throughout the year, vitamin D deficiency remains highly prevalent, with studies reporting prevalence rates ranging from 50% to 90% in different populations (5).

Metabolic syndrome (MetS) is characterized by a cluster of interconnected metabolic abnormalities including central obesity, elevated blood pressure, hyperglycemia, hypertriglyceridemia, and reduced high-density lipoprotein cholesterol (HDL-C) (6). Individuals with metabolic syndrome have a two-fold increased risk of cardiovascular disease and a five-fold increased risk of developing type 2 diabetes mellitus (7). The prevalence of metabolic syndrome has increased substantially worldwide due to changes in dietary habits, reduced physical activity, and rising obesity rates (8).

Several biological mechanisms have been proposed to explain the association between vitamin D deficiency and metabolic syndrome. Vitamin D receptors are present in pancreatic β-cells, adipose tissue, skeletal muscle, and vascular endothelial cells, suggesting a role in glucose metabolism and insulin sensitivity (9). Vitamin D deficiency may contribute to insulin resistance by impairing insulin secretion and increasing systemic inflammation (10). Furthermore, low vitamin D levels

have been linked to activation of the renin–angiotensin–aldosterone system, endothelial dysfunction, and increased adipogenesis, which are important contributors to metabolic syndrome (11).

Observational studies have demonstrated an inverse relationship between serum vitamin D levels and components of metabolic syndrome, including obesity, hypertension, dyslipidemia, and impaired glucose tolerance (12). However, some studies have reported inconsistent findings, indicating the need for further investigation in different populations (13). Understanding the relationship between vitamin D deficiency and metabolic syndrome may provide opportunities for early intervention and prevention of cardiometabolic diseases.

Therefore, the present study was undertaken to assess the association between vitamin D deficiency and metabolic syndrome among adults attending a tertiary care hospital and to evaluate the relationship between vitamin D status and individual components of metabolic syndrome.

MATERIALS AND METHODS

A hospital-based cross-sectional study was conducted in the Department of General Medicine of a tertiary care teaching hospital over a period of six months.

Study Population

Adults aged between 20 and 60 years attending the outpatient department and undergoing routine health evaluation were included in the study.

Sample Size

A total of 200 participants were enrolled using convenient sampling. The sample size was considered adequate to detect a significant association between vitamin D deficiency and metabolic syndrome with 95% confidence and 80% power.

Inclusion Criteria

1. Adults aged 20–60 years.
2. Individuals willing to provide informed consent.
3. Participants undergoing fasting biochemical investigations.

Exclusion Criteria

1. Pregnant and lactating women.
2. Patients with chronic liver disease or chronic kidney disease.
3. Individuals receiving vitamin D supplementation during the previous six months.
4. Patients with endocrine disorders affecting vitamin D metabolism.
5. Individuals on corticosteroid therapy.

Data Collection

After obtaining informed consent, demographic information including age, gender, occupation, physical activity, dietary habits, and medical history was collected using a structured questionnaire.

Anthropometric Measurements

Height was measured using a stadiometer and weight using a calibrated weighing scale. Body mass index (BMI) was calculated as weight (kg)/height (m^2). Waist circumference was measured at the midpoint between the lower rib margin and iliac crest using a non-stretchable measuring tape.

Blood Pressure Measurement

Blood pressure was measured using a standardized sphygmomanometer after 5 minutes of rest. The average of two readings was recorded.

Biochemical Analysis

After overnight fasting for 8–12 hours, venous blood samples were collected. The following parameters were analyzed:

- Fasting blood glucose (FBG)
- Total cholesterol
- Triglycerides (TG)
- HDL cholesterol
- Serum 25-hydroxyvitamin D [25(OH)D]

Serum vitamin D concentration was measured using chemiluminescent immunoassay.

Classification of Vitamin D Status

- Deficient: <20 ng/mL
- Insufficient: 20–29 ng/mL
- Sufficient: ≥30 ng/mL

Diagnosis of Metabolic Syndrome

Metabolic syndrome was diagnosed according to NCEP ATP III criteria. Presence of any three of the following five criteria was considered diagnostic:

1. Waist circumference >102 cm (men) or >88 cm (women)
2. Triglycerides ≥150 mg/dL
3. HDL cholesterol <40 mg/dL in men or <50 mg/dL in women
4. Blood pressure ≥130/85 mmHg
5. Fasting blood glucose ≥100 mg/dL

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 25. Continuous variables were expressed as mean ± standard deviation and categorical variables as frequencies and percentages. Chi-square test was used to assess association between categorical variables. Logistic regression analysis was performed to determine the independent association of vitamin D deficiency with metabolic syndrome. A p-value <0.05 was considered statistically significant.

Ethical Considerations

The study protocol was approved by the Institutional Ethics Committee. Written informed consent was obtained from all participants before enrollment.

RESULTS

Table 1: Distribution of Participants According to Vitamin D Status

Vitamin D Status	Frequency (n)	Percentage (%)
Deficient (<20 ng/mL)	120	60.0
Insufficient (20–29 ng/mL)	48	24.0
Sufficient (≥30 ng/mL)	32	16.0
Total	200	100

Vitamin D deficiency was observed in 60% of participants, indicating a high prevalence of inadequate vitamin D levels in the study population.

Table 2: Prevalence of Metabolic Syndrome According to Vitamin D Status

Vitamin D Status	MetS Present	MetS Absent	Total
Deficient	70	50	120
Insufficient	6	42	48
Sufficient	6	26	32

Chi-square = 24.8, p <0.001

Participants with vitamin D deficiency showed significantly higher prevalence of metabolic syndrome compared with those having sufficient vitamin D levels.

Table 3: Association Between Vitamin D Deficiency and Components of Metabolic Syndrome

Component	Deficient (%)	Sufficient (%)	p-value
Increased waist circumference	62.5	31.3	<0.001
Elevated blood pressure	55.8	28.1	0.002
Elevated fasting glucose	51.7	21.9	0.001
Hypertriglyceridemia	58.3	25.0	<0.001
Low HDL cholesterol	46.7	34.4	0.146

Vitamin D deficiency was significantly associated with increased waist circumference, hypertension, elevated fasting blood glucose, and hypertriglyceridemia. No statistically significant association was observed with low HDL cholesterol.

Table 4: Logistic Regression Analysis

Variable	Odds Ratio (OR)	95% CI	p-value
Vitamin D deficiency	3.42	1.76–6.65	<0.001
Age >40 years	1.89	1.03–3.48	0.039
Obesity	2.75	1.42–5.31	0.003

Vitamin D deficiency independently increased the risk of metabolic syndrome by approximately 3.4 times after adjusting for confounding factors.

DISCUSSION

The present study demonstrated a significant association between vitamin D deficiency and metabolic syndrome among adults. A high prevalence of vitamin D deficiency (60%) was observed, which is consistent with previous reports indicating widespread deficiency across various populations (3,5).

Metabolic syndrome was identified in 41% of participants, and its prevalence was significantly higher among individuals with vitamin D deficiency. These findings are in agreement with the study conducted by Ford et al., who reported an inverse association between serum vitamin D levels and metabolic syndrome prevalence in the United States population (14). Similarly, Lu et al. observed that lower vitamin D concentrations were associated with increased risk of metabolic syndrome and insulin resistance (15).

One possible explanation for this relationship is the role of vitamin D in glucose metabolism. Vitamin D receptors are expressed in pancreatic β-cells, and adequate vitamin D levels are necessary for optimal insulin secretion and sensitivity (9). Deficiency may impair insulin-mediated glucose uptake and promote insulin resistance, a central feature of metabolic syndrome (10).

The present study also found significant associations between vitamin D deficiency and individual components of metabolic syndrome, particularly central obesity, elevated blood pressure, fasting hyperglycemia, and hypertriglyceridemia. Similar findings have been reported by Vitezova et al., who observed that lower vitamin D levels were independently associated with adverse cardiometabolic risk factors (16).

Central obesity may contribute to lower vitamin D concentrations through sequestration of vitamin D within adipose tissue, reducing its bioavailability (17). Furthermore, obesity-related chronic inflammation may impair vitamin D metabolism and signaling pathways (18). The observed relationship between vitamin D deficiency and hypertension may be explained by activation of the renin–angiotensin–aldosterone system and endothelial dysfunction associated with low vitamin D levels (11).

Hypertriglyceridemia and elevated fasting glucose were significantly more common among vitamin D-deficient participants. Previous studies suggest that vitamin D may influence lipid metabolism through regulation of lipoprotein lipase activity and inflammatory mediators (19). Additionally, vitamin D deficiency has been linked to increased oxidative stress and systemic inflammation, both of which contribute to metabolic abnormalities (20).

Although low HDL cholesterol was more frequent among vitamin D-deficient individuals, the association did not reach statistical significance. Similar inconsistent findings have been reported in previous studies, suggesting that HDL metabolism may be influenced by multiple factors beyond vitamin D status (13).

The strengths of the present study include assessment of both metabolic syndrome and its individual components using standardized criteria. However, the cross-sectional design limits the ability to establish causality. Furthermore, the study was conducted in a single center and may not be representative of the general population.

Future prospective studies and randomized controlled trials are needed to determine whether correction of vitamin D deficiency can prevent or improve metabolic syndrome and its associated complications.

CONCLUSION

Vitamin D deficiency is highly prevalent among adults and is significantly associated with metabolic syndrome. Individuals with low vitamin D levels demonstrated higher rates of central obesity, hypertension, hyperglycemia, and hypertriglyceridemia. Vitamin D deficiency emerged as an independent predictor of metabolic syndrome. Routine screening and appropriate management of vitamin D deficiency may play an important role in reducing cardiometabolic risk and improving overall health outcomes.

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