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Original Research Article

RELATIONSHIP BETWEEN SERUM VITAMIN D LEVELS AND INDIVIDUAL COMPONENTS OF METABOLIC SYNDROME IN SOUTH INDIAN ADULTS

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ABSTRACT

Background: Low levels of vitamin D have been associated with the development of metabolic syndrome (MetS); however, its association with individual MetS components is not clear, especially in Indians. **Objectives:** To assess the relationship between serum vitamin D and each component of MetS, such as waist circumference, glucose profile, lipid profiles, and blood pressure. **Materials and Methods:** This cross-sectional analytical study was conducted on 146 adults (73 patients with MetS and 73 controls) from a tertiary care hospital in South India. Serum 25(OH)D was quantified by chemiluminescent immunoassay. Anthropometric measurements, fasting blood sugar, lipid profile, and blood pressure were evaluated. The relationship between vitamin D and metabolic parameters was examined using a correlation analysis.
Results: Serum vitamin D was inversely correlated with waist ($r = –0.19$, $p = 0.022$), fasting blood sugar ($r = –0.31$, $p < 0.001$), triglycerides ($r = –0.24$, $p = 0.004$), and SBP ($r = –0.33$, $p< 001$). Vitamin D was not significantly correlated with HDL cholesterol ($r = 0.14$, $p = 0.105$).
Conclusion: Reduced serum vitamin D levels are related to unfavorable cardiometabolic risk profiles in individuals with adult metabolic syndrome. These results imply that vitamin D may be involved in the regulation of specific metabolic components of MetS, regardless of classification as a syndrome.
Keywords: Vitamin D, metabolic syndrome components, waist circumference, triglycerides, fasting blood sugar, blood pressure.

INTRODUCTION

Metabolic syndrome (MetS) is a confluence of metabolic abnormalities, which together lead to elevated risk for cardiovascular disease and type 2 diabetes mellitus.[1] Although the syndrome is usually considered to be a single clinical entity, its components (central obesity, dysglycemia, dyslipidemia, and hypertension) have varied pathophysiology and clinical impact.[2] Investigating factors that impact these components independently may provide more specific points for prevention and intervention.

Vitamin D deficiency has become a public health issue worldwide, and it is especially widespread in South Asian people.[3] In addition to its well-known involvement in skeletal metabolism, vitamin D is gaining growing importance as a metabolic regulator.[4] Vitamin D receptors have been identified in adipose tissue, pancreatic β-cells, vascular endothelium, and skeletal muscle, indicating a potential involvement in insulin sensitivity, lipid metabolism, and vascular function.[5]

In this respect, several studies have found links between low vitamin D levels and individual MetS factors, such as large waist circumference, high fasting glucose levels, hypertriglyceridemia, and hypertension.[6] Potential mechanisms comprise deranged insulin secretion, enhanced systemic inflammation, disturbed adipokine release, and renin–angiotensin system activation. Nonetheless, results so far have been inconsistent, and the relation seems to differ according to ethnicity, behavior, and environmental background.

The relationship between vitamin D status and cardiometabolic risk factors deserves further

exploration in the Indian scenario, where there is plenty of sunlight available and still a high prevalence of vitamin D deficiency.[7] Although several previous investigations have addressed MetSas a binary phenomenon, few have examined the association of vitamin D with the severity and pattern of metabolic traits specifically among South Indian subjects.

The current study aimed to clarify the association of serum 25(OH)D with each component of metabolic syndrome, focusing on anthropometric indices, glycemic profiles, lipid profiles, and blood pressure as well. Through a component-wise perspective, our study intends to offer more detailed understandings of the metabolic role of vitamin D that transcends syndrome-based categories.

MATERIALS AND METHODS

Study design and setting

This cross-sectional analytical study was carried out in MES Medical College, Kerala, a tertiary care teaching hospital in South India serving the urban and rural population. The study was conducted for a period of one year, from March 2013 to March 2014, after seeking approval from the Institutional Ethical Committee. All subjects provided written consent at the time of enrollment.

Study Population

A hundred and forty-sixadults were recruited in the study. The samples included 73 subjects with MetS and 73 age- and sex-matched healthy controls. Eligible participants were selected from the outpatient service when they came for their regular checkup and follow-up.

Metabolic syndrome was defined based on the National Cholesterol Education Program Adult Treatment Panel III [NCEP ATP (III)] criteria, which required three or more of the following: increased waist circumference; elevated fasting plasma glucose; raised triglycerides; low HDL-cholesterol level; and high blood pressure or being under treatment for these factors.

Inclusion and exclusion criteria

Adult men and women aged 20-60 years were included. Exclusion criteria included established chronic renal, hepatic, endocrine (other than diabetes mellitus), cardiovascular, or skeletal pathologies; acute illness at the time of assessment; pregnancy or lactation; and a diagnosis of vitamin D or calcium supplementation in the last 6 months.

Clinical and anthropometric assessment

A structured proforma was used to elicit a detailed clinical history and demographic profile. Anthropometric data including height, weight, and waist circumference, were measured by standard methods. Body mass index (BMI) was defined as weight in kg divided by the square of height in meters (kg/m^2).

BP was recorded with the subjects sitting for at least 5 minutes and in response to taking no meals during the previous half hour, by a trained assistant (nurse) using a standard sphygmomanometer calibrated with mercury. Two measurements each were recorded with an interval of 5 minutes, and the mean value was reported.

Laboratory investigations

Venous blood samples were taken under aseptic precautions following a 10–12 h overnight fast. Serum was collected and subjected to biochemical estimation.

Serum 25-hydroxyvitamin D [25(OH)D] concentration was quantified by chemiluminometric immunoassay on an automated analyzer (Vitros 5600, Ortho Clinical Diagnostics). The serum levels of vitamin D were divided into three groups: deficient (<20 ng/ml), insufficient (20–29 ng/ml), and sufficient (≥30 ng/ml).

The concentration of fasting blood glucose was determined by the glucose oxidase–peroxidase method. The lipid profile components: total cholesterol and triglycerides were estimated by the enzymatic colorimetric method. HDL cholesterol concentration was determined after precipitation of other lipoproteins and LDL cholesterol was computed by the Friedewald formula. Serum calcium and phosphorus were analyzed on a colorimeter (Technicon CA II) using routine techniques.

Statistical Analysis

The data were coded and then analyzed with Statistical Package for the Social Sciences (SPSS) version 16.0 (SPSS Inc., Chicago, IL, USA). For continuous variables, mean ± standard deviation (SD) was used. The correlation of serum vitamin D concentrations with the separate components of metabolic syndrome, including waist circumference, fasting blood glucose, lipid profile, and blood pressure were also calculated using Pearson's r correlation coefficient. A p-value < 0.05 was considered statistically significant.

RESULTS

A total of 146 adults, including those with metabolic syndrome and age- and sex-matched control subjects participated in the analysis. Data for serum vitamin D concentrations and cardiometabolic risk factors were obtained from all subjects.

Serum vitamin D levels

On average, the serum 25-hydroxyvitamin D [25(OH)D] level was low in the population, indicating a high proportion of individual with vitamin D deficiency. A large percentage of subjects had insufficient serum 25(OH)D levels (less than 20 ng/ml).

Correlation of vitamin D with anthropometric and metabolic parameters

Correlation results showed significant negative associations between serum vitamin D and some of the metabolic syndrome features.

Serum vitamin D was significantly inversely correlated with waist circumference (r = – 0.19, p = 0.022), demonstrating that central obesity is associated directly with lower vitamin D levels. A more pronounced inverse correlation was found between vitamin D levels and FBS values (r = –0.31, p < 0.001), confirming a possible link between hypovitaminosis D and glycemic disorder.

Table 1: Correlation between serum vitamin D levels and components of metabolic syndrome

Metabolic parameter	Correlation coefficient (r)	p-value
Waist circumference (cm)	–0.19	0.022
Fasting blood sugar (mg/dl)	–0.31	<0.001
Triglycerides (mg/dl)	–0.24	0.004
Systolic blood pressure (mmHg)	–0.33	<0.001
HDL cholesterol (mg/dl)	+0.14	0.105

Values are the mean and Pearson's correlation coefficient (r). Statistical significance was set at p-values <0.05.

Similarly, serum vitamin D concentrations were inversely associated with triglycerides (r = –0.24, p = 0.004). Furthermore, there was a significant negative correlation between systolic blood pressure and vitamin It showed a higher value of blood pressures among those with lower levels of vitamin D (r = –0.33, p < 0.001).

There was no statistically significant correlation between serum vitamin D level and HDL cholesterol (r = 0.14, p = 0.105).

Summary of correlations

The correlations between serum vitamin D and waist circumference, fasting blood sugar, triglycerides, and systolic blood pressure are illustrated in Figure 1.

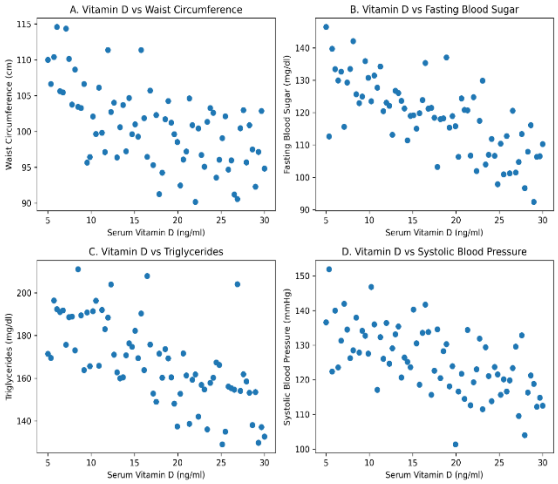

Figure 1: Correlation of serum vitamin D levels with components of metabolic syndrome

Scatter plots on the relationship between serum 25-hydroxyvitamin D [25(OH)D] and (A) waist circumference, (B) fasting blood sugar, (C) triglyceride, and (D) systolic blood pressure. Serum 25-OH, vitamin D showed significant inverse associations with waist circumference, fasting blood sugar, triglycerides, and systolic blood pressure, and no association was found with HDL cholesterol.

These results point to a general stereotype in which low vitamin D levels are linked with unfavorable anthropometric and metabolic statuses.

DISCUSSION

The present study explored the association of serum vitamin D with independent components of metabolic syndrome rather than treating it as a single entity. Low serum levels of vitamin D are found to be significantly associated with adverse anthropometric, glycemic, lipid, and blood pressure measurements.[8] These findings propose a possible role of Vitamin D deficiency in affecting several cardiometabolic pathways together, and the severity of abnormalities.

Direct significant correlation was found between serum vitamin D and waist circumference, suggesting a possible connection between hypovitaminosis D and central obesity.[9] Vitamin D is sequestered in the adipose tissue, lowering vitamin D availability and providing a potential mechanism for lower circulating levels in obese individuals with increased visceral fat.[10] By contrast, vitamin D itself can impact adipocyte differentiation and lipid storage, implying a reciprocal relationship between adiposity (central over peripheral) and the availability of vitamin D.

The only significant relationship in the present study was between serum vitamin D and FBS. This discovery helps to confirm previous data that vitamin D is involved in the metabolism of glucose. Pancreatic β-cells express vitamin D receptors, and vitamin D is known to increase insulin secretion and sensitivity in peripheral tissues. Such deficiency may thus play a role in the impairment of glucose homeostasis with potential for dysglycemia and progression to type 2 diabetes mellitus.

There was a strong and significant inverse association between serum triglycerides and vitamin D levels. Vitamin D is believed to influence lipid metabolism by its effects on both hepatic triglyceride synthesis and clearance, as well as via its anti-inflammatory properties. Elevated triglycerides are a hallmark of metabolic syndrome and a key contributor to cardiovascular risk, which renders this association clinically significant.

There was also an inverse relationship between vitamin D and systolic blood pressure. Vitamin D has been implicated in blood pressure regulation by suppression of the renin–angiotensin–aldosterone system and improvement of endothelial function. As such, a deficiency can lead to elevated vascular tone

and hypertension. This lack of magnitudinal association with dBP indicates that vitamin D might have a stronger influence on arterial stiffness and sBP.

There was no statistically significant relationship between serum vitamin D and HDL cholesterol. Some studies have found a positive relationship51, but others have had effects similar to those reported here. This discrepancy may be due to differences in the populations studied, dietary habits, physical activities, or genetic lipid metabolism factors. The effects on the metabolism of triglycerides might be more marked than for HDL cholesterol and may account for a decrease in life-style related hypertriglyceridemia.

The results of this study are especially germane in the Indian scenario with abundant sunshine but high pandemic rates of vitamin D deficiency. Concomitant hypovitaminosis D with deleterious metabolic profiles emphasizes the necessity to incorporate vitamin D status in a comprehensive cardiometabolic evaluation. Unlike syndrome-based screening, the assessment of each metabolic component also enables more specific preventive strategies.

This study has certain limitations. It is cross-sectional and this makes it impossible to conclude causality, and there may be residual confounding from unmeasured factors (e.g., diet, physical activity, and sun exposure). Parathyroid hormone levels were also not measured, which may have shed more light on the calcium–vitamin D interactions. However, the study is robust due to its standardized measurements and recruitment of cases and controls, as well as emphasis on component-specific associations in a rarely studied South Indian population.

In conclusion, the current study showed that decreased serum vitamin D level is linked to increased waist circumference, poor control of blood sugar, and hypertriglyceridemia as well as higher systolic blood pressure. These results reinforce the hypothesis that inadequate levels of vitamin D may participate in the metabolic disturbances associated with metabolic syndrome, and highlight the need for future prospective interventional studies to elucidate its specific role in cardiometabolic health.

CONCLUSION

Results from this study indicate that low serum vitamin D levels are significantly associated with numerous adverse cardiometabolic risk factors such as high waist circumference, high fasting blood sugar, high triglyceride levels, and elevated systolic blood pressure. These results imply that vitamin D deficiency may impact more than one facet of metabolic syndrome and does not simply work through a single metabolic mechanism. Considering vitamin D status with traditional metabolic risk factors could thus contribute to a better understanding of cardiometabolic health, especially in populations experiencing high hypovitaminosis D.

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Authors' contributions

The study protocol was developed by the research group. Investigators were also responsible for data collection and laboratory analysis. Physical examination was performed, and the results were interpreted jointly. All authors contributed to the submission and critical revision of the manuscript for intellectual content; they all read and approved the final version.

Conflict of interest

The authors declare that there is no conflict of interest related to this study.

REFERENCES

1. Hayden MR. Overview and new insights into the metabolic syndrome: risk factors and emerging variables in the development of type 2 diabetes and cerebrocardiovascular disease. Medicina. 2023 Mar 13;59(3):561.
2. Patial R, Batta I, Thakur M, Sobti RC, Agrawal DK. Etiology, pathophysiology, and treatment strategies in the prevention and management of metabolic syndrome. Archives of internal medicine research. 2024 Oct 28;7(4):273.
3. Siddiqee MH, Bhattacharjee B, Siddiqi UR, MeshbahurRahman M. High prevalence of vitamin D deficiency among the South Asian adults: a systematic review and meta-analysis. BMC public health. 2021 Oct 9;21(1):1823.
4. Bouillon R, Bikle D. Vitamin D metabolism revised: fall of dogmas. Journal of Bone and Mineral Research. 2019 Nov 1;34(11):1985-92.
5. Szymczak-Pajor I, Drzewoski J, Śliwińska A. The molecular mechanisms by which vitamin D prevents insulin resistance and associated disorders. International journal of molecular sciences. 2020 Sep 11;21(18):6644.
6. Barbalho SM, Tofano RJ, de Campos AL, Rodrigues AS, Quesada K, Bechara MD, de Alvares Goulart R, Oshiiwa M. Association between vitamin D status and metabolic syndrome risk factors. Diabetes & Metabolic Syndrome: Clinical Research & Reviews. 2018 Jul 1;12(4):501-7.
7. Upadhyay MP. Determinants of Vitamin D Deficiency in Patients with Bone Disorders in India (Master's thesis, Lithuanian University of Health Sciences (Lithuania)).
8. Khodabakhshi A, Mahmoudabadi M, Vahid F. The role of serum 25 (OH) vitamin D level in the correlation between lipid profile, body mass index (BMI), and blood pressure. Clinical Nutrition ESPEN. 2022 Apr 1;48:421-6.
9. Migliaccio S, Di Nisio A, Mele C, Scappaticcio L, Savastano S, Colao A, Obesity Programs of nutrition, Education, Research and Assessment (OPERA) Group. Obesity and hypovitaminosis D: causality or casualty?. International journal of obesity supplements. 2019 Apr;9(1):20-31.
10. Cimini FA, Sentinelli F, Oldani A, Barchetta I, Cavallo MG. Adipose tissue dysfunction and metabolic diseases: The role of vitamin D/vitamin D receptor axis. International Journal of Molecular Sciences. 2025 Oct 22;26(21):10256.