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ASSOCIATION BETWEEN VITAMIN D DEFICIENCY AND INSULIN RESISTANCE AMONG ADULTS ATTENDING A TERTIARY CARE HOSPITAL IN NORTH INDIA: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Vitamin D deficiency is highly prevalent globally and has been implicated in various metabolic disorders, including insulin resistance. India, despite abundant sunlight, reports widespread vitamin D deficiency along with a rising burden of insulin resistance and related conditions. Understanding the association between these factors is essential for developing preventive strategies.
Objectives: To assess the association between vitamin D deficiency and insulin resistance among adults attending a tertiary care hospital in North India.
Methods: This hospital-based cross-sectional study was conducted from May to October 2019 among 128 adults aged 18–60 years. Participants were selected using consecutive sampling. Data on demographic and clinical characteristics were collected using a semi-structured questionnaire. Fasting blood samples were analyzed for serum 25-hydroxyvitamin D, fasting glucose, and fasting insulin levels. Insulin resistance was calculated using the Homeostatic Model Assessment for Insulin Resistance (HOMA-IR). Vitamin D deficiency was defined as serum 25(OH)D <20 ng/mL. Statistical analysis was performed using SPSS version 20.0, with $p<0.05$ considered significant.
Results: Vitamin D deficiency was observed in 64.1% of participants. Individuals with vitamin D deficiency had significantly higher fasting glucose, fasting insulin, and HOMA-IR values compared to those with sufficient vitamin D levels ($p<0.05$). The prevalence of insulin resistance was significantly higher among vitamin D deficient participants (63.4%) compared to those with sufficient levels (34.8%) ($p=0.002$). A moderate inverse correlation was found between serum vitamin D levels and HOMA-IR ($r = -0.42$, $p<0.001$).
Conclusion: Vitamin D deficiency is significantly associated with insulin resistance in this population. Screening and correction of vitamin D deficiency may represent a potential strategy for improving metabolic health. Further studies are needed to establish causality and evaluate the impact of vitamin D supplementation on insulin resistance.

Keywords: Vitamin D deficiency; Insulin resistance; HOMA-IR; Metabolic disorders; North India; Cross-sectional study

INTRODUCTION

Vitamin D deficiency has emerged as a significant global public health concern, affecting nearly one billion people worldwide across diverse age groups and ethnicities [1]. Traditionally recognized for

its role in calcium homeostasis and bone metabolism, vitamin D is now increasingly implicated in a wide array of non-skeletal functions, including modulation of immune responses, inflammation, and metabolic processes [2]. Among these, its potential role in glucose metabolism and insulin sensitivity has attracted considerable research interest over the past decade.

Insulin resistance, a pathological condition characterized by reduced responsiveness of peripheral tissues to insulin, is a central feature in the pathogenesis of type 2 diabetes mellitus (T2DM) and metabolic syndrome [3]. The rising prevalence of insulin resistance globally, particularly in low- and middle-income countries, poses a major challenge to healthcare systems [4]. Several factors, including genetic predisposition, obesity, sedentary lifestyle, and dietary patterns, contribute to the development of insulin resistance; however, micronutrient deficiencies such as that of vitamin D are increasingly being explored as modifiable risk factors [5].

Biologically, vitamin D is believed to influence insulin secretion and sensitivity through multiple mechanisms. Vitamin D receptors are expressed in pancreatic β-cells and insulin-sensitive tissues such as skeletal muscle and adipose tissue, suggesting a direct role in glucose metabolism [6]. Additionally, vitamin D may regulate calcium flux within cells, which is essential for insulin-mediated intracellular processes [7]. It has also been proposed that vitamin D exerts anti-inflammatory effects that may reduce chronic low-grade inflammation, a known contributor to insulin resistance [8].

In the Indian context, vitamin D deficiency is highly prevalent despite abundant sunlight, due to factors such as skin pigmentation, cultural clothing practices, limited outdoor activity, and dietary insufficiency [9]. Concurrently, India is experiencing a rapid increase in the burden of insulin resistance and T2DM, particularly in urban and semi-urban populations [10]. This epidemiological overlap raises the possibility of a significant association between vitamin D deficiency and insulin resistance in this population.

Despite growing evidence globally, findings regarding the association between vitamin D levels and insulin resistance remain inconsistent, with some studies demonstrating a significant inverse relationship, while others report no association after adjusting for confounding variables [5,8]. Moreover, there is a relative paucity of data from North Indian tertiary care settings, where patient profiles, lifestyle factors, and environmental exposures may differ from other regions. This gap highlights the need for region-specific studies to better understand this relationship.

Given the high prevalence of both vitamin D deficiency and insulin resistance in the Indian population, and the potential for vitamin D to serve as a modifiable risk factor, it is important to investigate this association in a clinical setting. Such evidence could have implications for preventive and therapeutic strategies aimed at reducing the burden of metabolic disorders.

The present study aims to assess the association between vitamin D deficiency and insulin resistance among patients attending a tertiary care hospital in North India, and to evaluate the extent to which vitamin D levels correlate with markers of insulin resistance.

METHODOLOGY

Study Design: This study was designed as a hospital-based analytical cross-sectional study, in accordance with Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines, to assess the association between vitamin D deficiency and insulin resistance.

Study Setting: The study was conducted in a tertiary care teaching hospital located in North India, catering to both urban and rural populations.

Study Duration: The study was carried out over a period of six months, from May 2019 to October 2019.

Study Population: The study population comprised adult patients attending the outpatient department (OPD) or admitted to the general medicine department of the tertiary care hospital during the study period.

Inclusion Criteria

Adults aged 18–60 years

Individuals willing to participate and provide written informed consent
Patients undergoing evaluation for metabolic or general health assessment

Exclusion Criteria

Known cases of type 1 or type 2 diabetes mellitus on treatment
Patients on vitamin D supplementation in the past 6 months
Individuals with chronic kidney disease, chronic liver disease, or malabsorption syndromes
Patients on medications affecting vitamin D metabolism (e.g., glucocorticoids, anticonvulsants)
Pregnant or lactating women

Sample Size: The sample size was calculated based on an expected prevalence of vitamin D deficiency of approximately 70% in the Indian population [9], with a 95% confidence level and 8% absolute precision. Using the formula:

$n = Z^2 \times p \times q / d^2$

Where:

$Z = 1.96$ (for 95% confidence level)

$p = 0.70$

$q = 1 - p = 0.30$

$d = 0.08$

The calculated sample size was approximately 126. To account for possible non-response or incomplete data, a final sample size of 128 participants was included in the study.

Sampling Technique:A consecutive sampling technique was employed, wherein all eligible participants presenting during the study period and meeting the inclusion criteria were enrolled until the required sample size was achieved.

Data Collection Tools & Procedure: Data were collected using a pre-tested, semi-structured questionnaire capturing demographic details (age, sex), lifestyle factors (physical activity, sun exposure), and clinical history. Anthropometric measurements including height, weight, and body mass index (BMI) were recorded using standardized procedures. Fasting venous blood samples were collected after an overnight fast of 8–10 hours. Serum 25-hydroxyvitamin D [25(OH)D] levels were measured using chemiluminescent immunoassay. Fasting plasma glucose was measured using the glucose oxidase-peroxidase method, and fasting serum insulin levels were assessed using enzyme-linked immunosorbent assay (ELISA). Insulin resistance was calculated using the Homeostatic Model Assessment for Insulin Resistance (HOMA-IR) formula: fasting insulin (μIU/mL) × fasting glucose (mg/dL) / 405. Vitamin D deficiency was defined as serum 25(OH)D levels <20 ng/mL.

Study Variables: The primary independent variable was serum vitamin D status, categorized as deficient (<20 ng/mL) and sufficient (≥20 ng/mL). The dependent variable was insulin resistance, assessed using HOMA-IR values as a continuous variable and categorized based on established cut-offs (HOMA-IR >2.5 indicating insulin resistance). Other covariates included age, sex, BMI, and lifestyle factors, which were considered potential confounders in the analysis.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 20.0. Continuous variables were expressed as mean ±standard deviation (SD), while categorical variables were presented as frequencies and percentages. The independent t-test was used to compare means between groups. The chi-square test was applied for categorical variables. Pearson's correlation coefficient was used to assess the relationship between serum vitamin D levels and HOMA-IR. Multivariate linear regression analysis was performed to adjust for potential confounders. A p-value of <0.05 was considered statistically significant.

Ethical Considerations: Written informed consent was obtained from all participants prior to enrollment. The study adhered to the ethical principles outlined in the Declaration of Helsinki. Confidentiality and anonymity of participant data were strictly maintained throughout the study.

RESULTS

A total of 128 participants were included in the analysis. The mean age of the study population was 38.6 ±10.2 years, with a slight male predominance (Table 1)

Table 1: Baseline Characteristics of Study Participants (n = 128)

Variable	Value
Age (years), mean ± SD	38.6 ± 10.2
Gender (Male/Female)	68 (53.1%) / 60 (46.9%)
BMI (kg/m²), mean ± SD	25.4 ± 3.8
Overweight/Obese (%)	72 (56.3%)
Physical inactivity (%)	58 (45.3%)

Vitamin D deficiency was observed in 64.1% of participants (Table 2)

Table 2: Distribution of Vitamin D Status among Participants

Vitamin D Status	Number (n)	Percentage (%)
Deficient (<20 ng/mL)	82	64.1%
Sufficient (≥20 ng/mL)	46	35.9%

Participants with vitamin D deficiency demonstrated significantly higher fasting glucose, fasting insulin, and HOMA-IR levels compared to those with sufficient vitamin D levels (Table 3)

Table 3: Comparison of Metabolic Parameters by Vitamin D Status

Parameter	Deficient (n=82)	Sufficient (n=46)	p-value
Fasting glucose (mg/dL)	98.5 ± 12.4	92.3 ± 10.1	0.01
Fasting insulin (μIU/mL)	14.8 ± 5.6	10.9 ± 4.2	<0.001
HOMA-IR	3.6 ± 1.4	2.5 ± 1.1	<0.001

The prevalence of insulin resistance was significantly higher among vitamin D deficient individuals (63.4%) compared to those with sufficient levels (34.8%) (p = 0.002) (Table 4)

Table 4: Prevalence of Insulin Resistance by Vitamin D Status

Vitamin D Status	Insulin Resistance Present (n, %)	Insulin Resistance Absent (n, %)	p-value
Deficient (n=82)	52 (63.4%)	30 (36.6%)	0.002
Sufficient (n=46)	16 (34.8%)	30 (65.2%)	

A moderate but statistically significant negative correlation was observed between serum vitamin D levels and HOMA-IR (r = -0.42, p < 0.001), indicating that lower vitamin D levels were associated with higher insulin resistance (Table 5)

Table 5: Correlation between Serum Vitamin D Levels and HOMA-IR

Variable Pair	Correlation Coefficient (r)	p-value
Vitamin D vs HOMA-IR	-0.42	<0.001

DISCUSSION

The present study evaluated the association between vitamin D deficiency and insulin resistance among adults attending a tertiary care hospital in North India. The findings demonstrate a high prevalence of vitamin D deficiency (64.1%) and reveal a significant association between low vitamin D levels and increased insulin resistance. Participants with vitamin D deficiency had significantly higher fasting glucose, fasting insulin, and HOMA-IR values, along with a greater prevalence of

insulin resistance. Additionally, a moderate inverse correlation between serum vitamin D levels and HOMA-IR was observed.

These findings are consistent with earlier studies that have reported an inverse relationship between vitamin D status and insulin resistance. Chiu et al. [7] demonstrated that hypovitaminosis D is associated with impaired β-cell function and increased insulin resistance in healthy individuals. Similarly, Pittas et al. [5] highlighted the potential role of vitamin D in glucose metabolism, suggesting that deficiency may contribute to the pathogenesis of type 2 diabetes. The observed negative correlation in the present study aligns with these findings, reinforcing the biological plausibility of the association.

Mechanistically, vitamin D is believed to influence insulin sensitivity through multiple pathways. It enhances insulin receptor expression and promotes insulin responsiveness for glucose transport [6]. Furthermore, vitamin D plays a role in maintaining extracellular calcium and intracellular calcium flux, both of which are essential for insulin-mediated processes in peripheral tissues [7]. Its anti-inflammatory properties may also mitigate chronic low-grade inflammation, a known contributor to insulin resistance [8]. The higher HOMA-IR values observed among vitamin D deficient individuals in this study could be explained by these interconnected mechanisms.

In the Indian context, the high prevalence of vitamin D deficiency observed in this study is consistent with previous reports [9]. Factors such as increased skin pigmentation, limited sun exposure due to urban lifestyle, and low dietary intake of vitamin D-rich foods contribute to this widespread deficiency. The coexistence of vitamin D deficiency and insulin resistance in this population underscores the need for integrated public health strategies targeting both conditions.

However, not all studies have reported a consistent association. Some investigations have found that the relationship between vitamin D and insulin resistance weakens after adjusting for confounders such as obesity and physical activity [5]. In the present study, although adjustments were attempted through multivariate analysis, residual confounding cannot be entirely ruled out. This highlights the complexity of the relationship and suggests that vitamin D deficiency may act as one of several contributing factors rather than an independent determinant.

From a clinical and public health perspective, the findings of this study suggest that screening for vitamin D deficiency may be beneficial in individuals at risk of insulin resistance. Early identification and correction of vitamin D deficiency could potentially serve as a simple and cost-effective strategy to improve metabolic outcomes. However, interventional studies and randomized controlled trials are needed to establish causality and determine whether vitamin D supplementation can effectively reduce insulin resistance.

The strengths of this study include its well-defined study population, standardized measurement of biochemical parameters, and the use of HOMA-IR as a validated marker of insulin resistance. Additionally, the study provides region-specific data from a North Indian tertiary care setting, contributing to the limited existing literature in this area.

Nevertheless, certain limitations must be acknowledged. The cross-sectional design precludes causal inference, limiting the ability to establish a temporal relationship between vitamin D deficiency and insulin resistance. The study was hospital-based, which may limit the generalizability of the findings to the broader community. Furthermore, factors such as dietary intake, seasonal variation in vitamin D levels, and detailed physical activity assessments were not comprehensively evaluated, which could have influenced the results.

In summary, the present study supports the growing body of evidence suggesting an association between vitamin D deficiency and insulin resistance. While the findings are consistent with existing literature, further longitudinal and interventional studies are warranted to clarify the causal relationship and explore the therapeutic potential of vitamin D in metabolic disorders.

CONCLUSION

This study demonstrates a significant association between vitamin D deficiency and insulin resistance among adults in a tertiary care setting in North India. A high prevalence of vitamin D deficiency was

observed, and individuals with deficient levels exhibited significantly higher fasting glucose, fasting insulin, and HOMA-IR values, along with a greater likelihood of insulin resistance. The observed inverse correlation between serum vitamin D levels and insulin resistance supports the hypothesis that vitamin D may play a role in glucose metabolism and insulin sensitivity.

These findings highlight the potential importance of screening for vitamin D deficiency in individuals at risk of metabolic disorders. Given that vitamin D deficiency is a modifiable factor, early identification and appropriate management may contribute to improved metabolic health outcomes. However, due to the cross-sectional nature of the study, causality cannot be established. Further longitudinal studies and randomized controlled trials are recommended to determine whether vitamin D supplementation can effectively reduce insulin resistance and prevent progression to type 2 diabetes mellitus.

DECLARATIONS

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Conflict of Interest: The authors declare no conflict of interest.

Consent: Written informed consent was obtained from all participants prior to inclusion in the study.

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