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Original Article

Association of Obesity, Dyslipidemia, and Vitamin D Deficiency with Type 2 Diabetes Mellitus in Adults: A Hospital-Based Cross-Sectional Study

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A R T I C L E I N F O

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A B S T R A C T

Background: Type 2 diabetes mellitus is an increasing public health challenge in India and is strongly associated with obesity, dyslipidemia, and vitamin D deficiency. While each factor has independently been linked to the pathogenesis of T2DM, little evidence exists regarding the combined metabolic burden of these factors in relation to T2DM. This study aimed to evaluate the combined association of obesity, dyslipidemia, and vitamin D status with diabetes. Methods: A hospital-based analytical cross-sectional study was conducted among 250 adult outpatients. The analysis included various anthropometric and biochemical parameters such as lipid profile and serum vitamin D levels. Data were analyzed using multivariate logistic regression, combined metabolic burden analysis, and ROC analysis. Results: Out of 250 participants, 69 (27.6%) participants had diabetes. participants with diabetes had significantly elevated BMI, TG levels, and LDL levels, while HDL levels and vitamin D levels were significantly lower in comparison with non-diabetic participants ($p < 0.001$). Multivariable analysis showed that BMI (aOR 1.45, 95% CI 1.31-1.63), TG (aOR 1.03, 95% CI 1.02-1.05) and HDL (aOR 0.92, 95% CI 0.84-0.99) were independently associated with diabetes, while vitamin D deficiency did not. The multivariable model had a significant discriminative ability (AUC = 0.924). Diabetes prevalence increased across metabolic burden categories; the prevalence of diabetes in the high metabolic burden category was 58.6%. Conclusion:Obesity and dyslipidemia were independently associated with diabetes, while vitamin D deficiency was associated with adverse metabolic clustering rather than acting as an independent determinant of diabetes.

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INTRODUCTION

Type 2 diabetes mellitus (T2DM) constitutes one of the largest public health problems worldwide due to chronic hyperglycemia resulting from defects in insulin secretion, insulin action, or both. The problem of diabetes has been increasing in magnitude for the past few decades owing to several reasons including urbanization, sedentary lifestyles, unhealthy dietary patterns, and obesity [1,2].

India is going through an epidemiological transition with a steady rise in diabetes prevalence [3]. This increase has been linked to changes in lifestyle, genetics, obesity, and other metabolic disorders [3,5].

Obesity is one of the most important modifiable risk factors for T2DM. Obesity promotes insulin resistance and low-grade inflammation, which contributes to the development of type 2 diabetes [6,7]. South Asians appear to be more prone to metabolic diseases at lower body mass index (BMI), known as the "Asian Indian phenotype". As such, lower BMI cut-off points should be used when assessing the risk of developing metabolic syndromes [6,7].

Dyslipidemia is another key contributor, characterized by increased triglycerides, LDL cholesterol, and decreased HDL levels [8–11]. Dyslipidemia results in the development of insulin resistance and β-cell dysfunction and is common among participants with diabetes in India.

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Recent research indicates that vitamin D plays a role in glucose metabolism besides the regulation of calcium homeostasis [12]. Deficiency in vitamin D may influence insulin secretion, glucose metabolism, and inflammation. Vitamin D deficiency has been associated with insulin resistance, poor β-cell function, as well as dyslipidemia and is more common among individuals with obesity [13–15]. In spite of the ample sunshine in India, vitamin D deficiency is highly prevalent due to skin pigmentation, urban lifestyle, lack of sunlight exposure, and inadequate dietary vitamin D intake [15].

There has been emerging evidence on a complex relationship between obesity, dyslipidemia, and vitamin D in metabolic dysfunction. For example, vitamin D deficiency may promote the development of insulin resistance as well as lipid anomalies in people with metabolic syndrome [13,18].

While the relationship between any single risk factor above and diabetes has been extensively studied, information on the combined effect of the three metabolic factors remains limited, especially in the context of hospitals in India. Thus, this study aimed to investigate the combined association of obesity, dyslipidemia, and vitamin D deficiency with diabetes among Indian adults attending hospitals.

MATERIALS AND METHODS

Study Design and Setting

A hospital-based analytical cross-sectional study was carried out at the outpatient department of S R Patil Medical College for 18 months from June 2024 to December 2025.

Study Population

The study population included adults aged ≥18 years and was categorized into with type 2 diabetes mellitus (T2DM) and non-diabetic participants, participants with diabetes were identified at the outpatient clinic, and non-diabetic participants were those attending for routine health check-ups or minor non-metabolic complaints.. Diabetic subjects were diagnosed according to American Diabetes Association guidelines [21], while the normal glycaemic status was confirmed in non-diabetic participants.

Sample Size

Initially, the sample size was calculated with a national diabetes prevalence of 8.9% using the following formula, $n = Z^2pq/d^2$; obtaining a minimum required sample of 124 participants. Further considering hospital-based design and need of multivariate logistic regression, sample size was determined using the events per variable (EPV) rule [22]. With 69 diabetes events and 5 predictor variables in the final model, the events-per-variable ratio was approximately 13.8, exceeding the recommended minimum threshold of 10. In addition, a sample size of 250 participants was used for sufficient statistical power and robust regression models.

Inclusion/Exclusion Criteria

Adults aged ≥18 years providing written consent were included in this study. Type 1 diabetes mellitus, chronic kidney disease, chronic liver disease, cancer, pregnancy, those on vitamin D supplementation or lipid-lowering therapy, and unwillingness to participate were excluded from the study.

Ethical Considerations

Prior ethical approval was obtained from the Institutional Ethics Committee of S R Patil Medical College. All participants provided written informed consent before enrollment in the study. Additional study-related investigations were covered by the investigators to avoid financial burden on participants.

Data Collection

Data were collected on a pre-designed and structured proforma. Sociodemographic parameters, anthropometry and biochemical parameters were documented. Weight and height were measured in a standard manner, while BMI was calculated as weight (kg) divided by height (m^2). Fasting venous blood samples were collected from each participant using aseptic precautions.

Biochemical Parameters and Operational Definitions

Biochemical investigations involved fasting blood glucose/HbA1c, lipid profile and serum 25-hydroxy vitamin D using standard laboratory methods. Diabetes was defined as per American Diabetes Association guidelines [21]. Obesity was defined using World Health Organization criteria for BMI classification [6], dyslipidaemia using NCEP ATP III guidelines [7], and vitamin D deficiency defined as serum 25-hydroxyvitamin D levels <20 ng/mL [12]. For metabolic burden analysis, metabolic abnormalities included obesity, hypertriglyceridemia, and vitamin D deficiency. Participants were categorized into no/minimal (0–1 abnormalities), moderate (2 abnormalities), and high (3 abnormalities) metabolic burden groups. Hypertriglyceridemia was defined as triglycerides ≥150 mg/dL and low HDL cholesterol as <40 mg/dL in men and <50 mg/dL in women, according to NCEP ATP III guidelines [7].

Statistical Analysis

Data were analyzed using R software (version 4.3.1). Continuous variables were expressed as mean ± standard deviation or median (interquartile range), while categorical variables were presented as frequencies and percentages. Appropriate parametric and non-parametric tests were used for group comparisons. Multivariable logistic regression and ROC analysis were performed to identify factors associated with diabetes and assess model performance. Statistical significance was considered at $p < 0.05$. LDL cholesterol was excluded from regression analysis due to multicollinearity and non-significance.

Outcome Measures

The primary outcome was to assess the association between metabolic burden and diabetes status.

RESULTS

A total of 250 participants were analyzed, of whom 69 (27.6%) had diabetes and 181 (72.4%) did not. There was no statistically significant difference in age between participants with and without diabetes [median (IQR): 60 (48-74) vs 65 (44-76); p=0.833], and also sex distribution was comparable between groups with males comprising 53.6% and 49.2%, respectively (p=0.626) (Table 1).

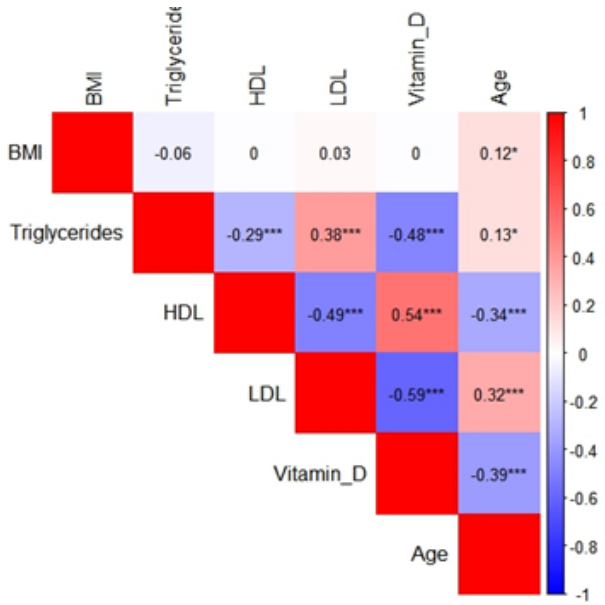
Table 1: Baseline Clinical and Biochemical Characteristics by Diabetes Status

Variable		No Diabetes (n = 181)	Diabetes (n = 69)	Test , p-value, Effect size (r)
Age (years)		60 (48–74)	65 (44–76)	W = 6136.5, p = 0.833, r = 0.01
Gender	Male	89 (49.2%)	37 (53.6%)	χ^2 = 0.238, p = 0.626, V = 0.04
	Female	92 (50.8%)	32 (46.4%)	
Body Mass Index (kg/m^2)		24.9 (22.0–30.3)	32.0 (29.8–34.2)	U = 2278, p < 0.001, r = 0.49
Triglycerides (mg/dL)		177 (156–220)	235 (207–256)	U = 2900.5, p < 0.001, r = 0.41
HDL Cholesterol (mg/dL)		42 (36–47)	40 (33–43)	U = 8122.5, p < 0.001, r = 0.23
LDL Cholesterol (mg/dL)		144 (130–171)	165 (141–181)	U = 4490.5, p < 0.001, r = 0.22
Vitamin D (ng/mL)		16.9 (13.0–24.2)	13.2 (11.2–15.2)	U = 8665, p < 0.001, r = 0.30

Participants with diabetes had less favorable metabolic parameters compared with non-diabetic participants. The median BMI was significantly higher in diabetic participants [32.0 (29.8-34.2) vs 24.9 (22.0-30.3) kg/m^2; p<0.001]. The median values of triglycerides were significantly higher in the diabetic group [235 (207-256) vs 177 (156-220) mg/dL] as well as median LDL levels [165 (141-181) vs 144 (130-171) mg/dL] (p<0.001). On the contrary, median HDL cholesterol and vitamin D levels were significantly lower among diabetic participants (p<0.001) (Table 1).

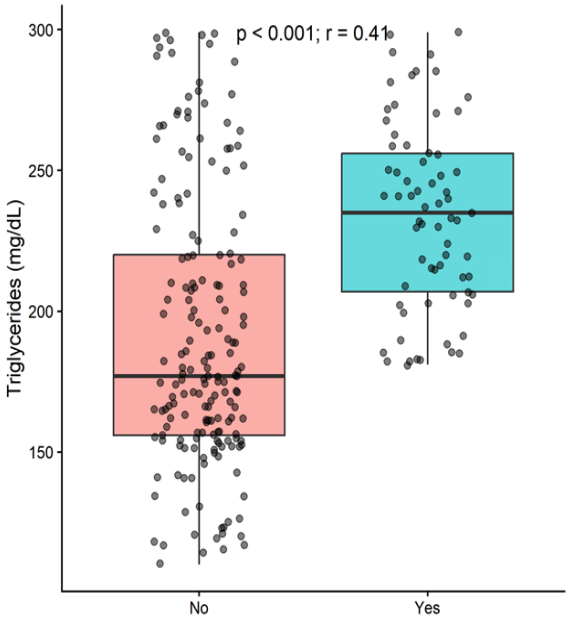
Spearman correlation analysis showed significant associations between metabolic parameters. Triglycerides were significantly inversely associated with HDL cholesterol (ρ=-0.29, p<0.001) and vitamin D levels (ρ=-0.48, p<0.001). HDL cholesterol was positively associated with vitamin D (ρ=0.54, p<0.001). Furthermore, LDL cholesterol was inversely associated with vitamin D (ρ=-0.59, p<0.001). Thus, lipid adverse parameters tend to cluster in the low vitamin D levels category (Figure 1).

Figure 1: Correlation Matrix of Metabolic Parameters



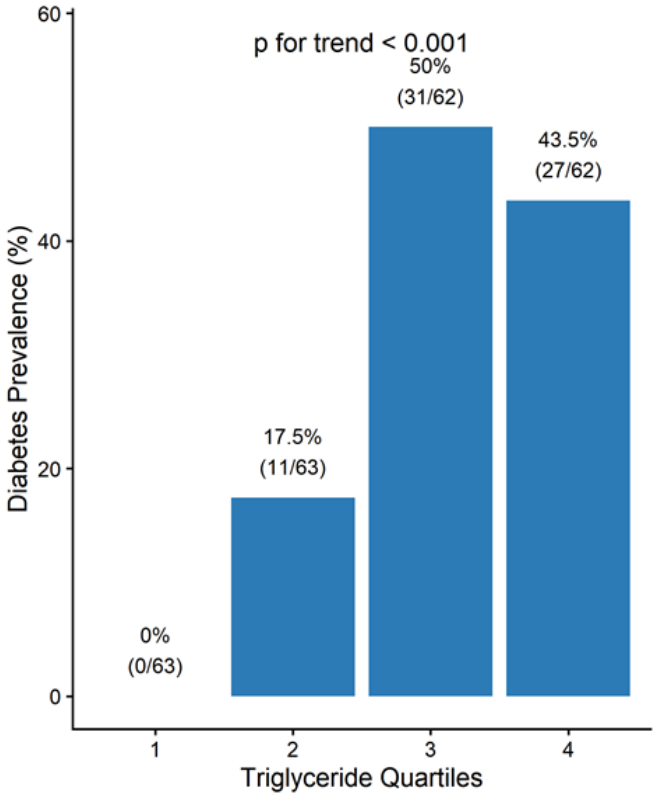
Triglyceride distributions differed significantly by diabetes status, with the diabetic group having higher triglycerides levels (Mann Whitney U test, p<0.001) and a moderate effect size (Figure 2).

Figure 2: Distribution of Triglyceride Levels by Diabetes Status



When stratified into triglyceride quartiles, there was a statistically significant dose–response relationship with increasing prevalence of diabetes (p for trend <0.001) (Figure 3).

Figure 3: Prevalence of Diabetes Across Triglyceride Categories



Multivariate logistic regression analysis showed that BMI, triglycerides, and HDL cholesterol were the significant factors associated with diabetes . Each one-unit increase in BMI was associated with a 45% higher odds of diabetes (adjusted OR 1.45, 95% CI 1.31-1.63; p<0.001). Triglycerides showed a strong, independent positive association with diabetes. While the model indicated an adjusted OR of 1.03 (95% CI 1.02–1.05) per 10 mg/dL increase, clinically this translates to a substantial 34% higher odds of diabetes for every 10 mg/dL increase in serum triglycerides (p < 0.001). Furthermore, HDL cholesterol showed an inverse association (adjusted OR 0.92, 95% CI 0.84-0.99; p=0.044). Age and vitamin D were not significantly associated with diabetes after adjusting the model (Table 2).

Table 2: Independent Factors Associated with Diabetes: Multivariable Logistic Regression Analysis

Variable	Adjusted OR (95% CI)	p-value
BMI (kg/m^2)	1.45 (1.31–1.63)	<0.001
Triglycerides (mg/dL)	1.03 (1.02–1.05)	<0.001
HDL (mg/dL)	0.92 (0.84–0.99)	0.044
Vitamin D (ng/mL)	0.92 (0.82–1.02)	0.12
Age (years)	0.96 (0.90–1.02)	0.18
Notes: Odds ratios represent per-unit increase. Model performance: AUC = 0.924; Hosmer–Lemeshow p = 0.879; Nagelkerke R^2 = 0.63.		

The multivariate model demonstrated high discriminative capability with an area under the curve of 0.924 (95% CI 0.893-0.956), sensitivity of 86.9%, and specificity of 82.3% (Figure 4).

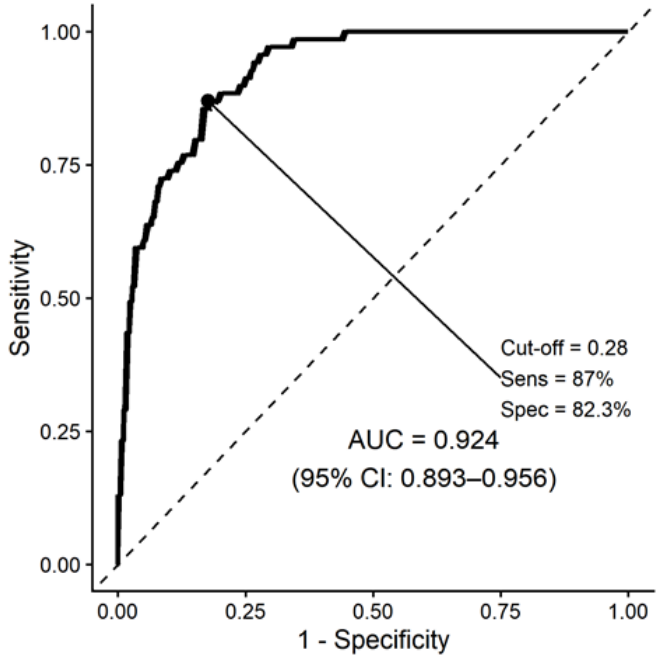


Figure 4: Receiver Operating Characteristic Curve for Diabetes Prediction

The restricted cubic spline analysis showed that the relationship between BMI and diabetes is non-linear with gradual increase in the probability of diabetes until approximately 27 kg/m^2 after which the slope starts steepening (Figure 5).

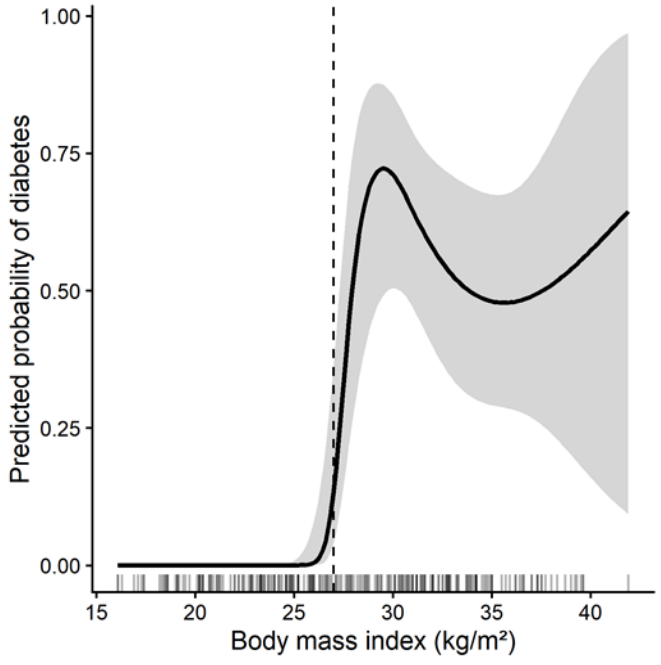


Figure 5: Non-linear Association Between Body Mass Index and Probability of Diabetes

Diabetes prevalence differed significantly across metabolic burden categories (p<0.001) . None of the participants had diabetes in case of no/ minimal metabolic burden. Diabetes prevalence was 3.9% in the moderate burden group and 58.6% in the high burden group (Table 3).

Table 3: Diabetes Prevalence by Metabolic Burden Category

Metabolic Burden Category	Definition	Total n	Diabetes n (%)
No/Minimal Metabolic Burden	0–1 metabolic abnormalities	37	0 (0.0)
Moderate Metabolic Burden	2 metabolic abnormalities	102	4 (3.9)
High Metabolic Burden	3 metabolic abnormalities	111	65 (58.6)
Fisher's Exact Test (Monte Carlo simulation): p < 0.001, Cramér's V: 0.620			

DISCUSSION

In the current study, the association between obesity, dyslipidemia, vitamin D status, and diabetes was evaluated. It appears that while metabolic factors including BMI and lipid profile abnormalities seem to be associated with diabetes status, vitamin D was associated with metabolic abnormalities but was not independently associated with diabetes.

Age and gender were not found to be associated with diabetes in the current study. This is in agreement with Indian epidemiological data showing increasing prevalence of diabetes without any gender preference when adjusted for metabolic factors [3,4]. In addition, some large population-based studies have found that metabolic factors could be stronger determinants of diabetes compared to demographic factors.

Obesity was strongly associated with diabetes in the current study. In agreement with this finding, global data indicate that people with BMI ≥25 kg/m^2 were at 2-3 times higher likelihood of diabetes [6,7]. The World Health Organization emphasizes that due to higher visceral adiposity and insulin resistance, Asians develop metabolic abnormalities at much lower BMI threshold values [6]. The "Asian Indian phenotype" further increases the risk of diabetes at lower BMI levels [7].

Dyslipidemia was significantly associated with diabetes status in this study. Both high levels of triglycerides and low HDL levels associated with diabetes independently from other metabolic correlates of diabetes. Several previous studies have reported that having the highest quartile of triglyceride levels correlates with two fold increased risk of diabetes, and those with the lowest quartile of HDL levels have a 30–50% increased risk [9,10]. Abnormal lipid profile is an essential element of metabolic syndrome [7] and is a common feature in Indians with diabetes [11].

A dose–response relationship between triglyceride levels and diabetes prevalence was found in the current study, in line with prior evidence. Furthermore, lipid ratios like triglyceride to HDL ratio have proven to be good indicators of metabolic syndrome [10].

Vitamin D deficiency was associated with adverse lipid profiles in the current study. Similar correlations were found in prior studies, where higher triglyceride levels and lower HDL levels were associated with vitamin D deficiency [16,17].

High prevalence rates of vitamin D deficiency are seen globally. According to systematic reviews, as many as 50–80% of participants with type 2 diabetes had vitamin D deficiency [14]. Despite sufficient solar exposure, vitamin D deficiency remains common in India due to lifestyle and skin pigmentation factors [15]. Vitamin D influences insulin resistance, insulin secretion, and inflammatory pathways [12,13].

However, after adjusting for metabolic factors, vitamin D was not independently associated with diabetes. This result has been corroborated in other studies and meta-analyses that attenuate the correlation between vitamin D deficiency and diabetes after adjustment for adiposity [13,14]. Diabetes prevalence increased with greater metabolic burden. Participants with high metabolic burden had the highest diabetes prevalence. Therefore, clustering of metabolic abnormalities could be helpful in identifying individuals at higher metabolic risk [16,18].

The clustering of obesity, dyslipidemia, and metabolic abnormalities observed in the present study is consistent with the metabolic syndrome concept proposed by Grundy and Reaven [19,20].

CONCLUSION

While obesity and dyslipidemia were strongly associated with diabetes, vitamin D deficiency was associated with adverse metabolic clustering but not independently associated with diabetes after adjustment. Higher BMI, elevated triglycerides, and lower HDL cholesterol were associated with diabetes. These findings suggest that diabetes is related to the overall metabolic profile rather than isolated factors. Integrated assessment of metabolic parameters may help identify high-risk individuals and guide preventive strategies.

LIMITATIONS

The cross-sectional hospital-based design limits causal inference and temporality. Unmeasured confounders such as diet, physical activity, sunlight exposure, and socioeconomic status may influence the outcomes. Biochemical parameters were measured at a single time point, and some subgroup analyses had small sample sizes. Longitudinal studies are needed to clarify these associations. No diabetes cases were observed in the low/minimal metabolic burden group, and some subgroup comparisons had sparse events.

Conflicting Interest (If present, give more details): No Conflicts of interest.

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