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Original Research Article

Thyroid Function, Insulin Resistance, and Visceral Adiposity Index in Type 2 Diabetes Mellitus: A Cross-Sectional Study

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Conflict of interest: Nil

Abstract:

Background: Thyroid dysfunction and visceral adiposity may contribute to metabolic abnormalities in individuals with type 2 diabetes mellitus (T2DM). This study evaluated the prevalence of subclinical hypothyroidism and the associations of thyroid-stimulating hormone (TSH) and visceral adiposity index (VAI) with insulin resistance in adults with T2DM.

Methods: This hospital-based, cross-sectional observational study included 85 adults with T2DM attending Patna Medical College and Hospital, Patna, India, between April 2025 and April 2026. Thyroid function, fasting plasma glucose, fasting insulin, lipid profile, and anthropometric measurements were assessed. Insulin resistance was estimated using the homeostasis model assessment of insulin resistance (HOMA-IR), and VAI was calculated using sex-specific equations. Group comparisons, Pearson correlation analysis, and multiple linear regression were reported.

Results: The mean age of participants was 51.4 ± 8.2 years, and 45 (52.9%) were male. Subclinical hypothyroidism was identified in 16 participants (18.8%). Compared with euthyroid participants, those with subclinical hypothyroidism had higher mean HOMA-IR (4.82 ± 1.15 vs. 3.37 ± 1.32; $p < 0.001$) and VAI (3.92 ± 0.88 vs. 2.61 ± 0.74; $p < 0.001$). TSH showed a positive correlation with HOMA-IR ($r = 0.428$; $p < 0.001$) and VAI ($r = 0.491$; $p < 0.001$). VAI was positively correlated with HOMA-IR ($r = 0.612$; $p < 0.001$). In the reported multivariable regression model, VAI ($\beta = 0.415$; $p < 0.001$) and TSH ($\beta = 0.284$; $p = 0.004$) were statistically significant correlates of HOMA-IR; the adjusted R^2 was 0.483.

Conclusion: In this cohort of adults with T2DM, subclinical hypothyroidism was relatively common and was associated with higher estimated insulin resistance and VAI. Higher TSH and VAI were also associated with higher HOMA-IR in the reported analyses. These findings support further investigation of thyroid function and adiposity-related metabolic indicators in T2DM, although the cross-sectional design precludes causal inference.

Keywords: Type 2 Diabetes Mellitus; Subclinical Hypothyroidism; Thyroid-Stimulating Hormone; Insulin Resistance; HOMA-IR; Visceral Adiposity Index.

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Introduction

Type 2 diabetes mellitus is a heterogeneous metabolic disorder involving insulin resistance and progressive impairment of pancreatic β-cell function. Its clinical expression often overlaps with abnormalities in lipid handling, adipose-tissue function, and endocrine regulation. Thyroid hormones influence energy expenditure, hepatic glucose production, lipid metabolism, and insulin action; thyroid dysfunction may therefore complicate metabolic assessment in people with diabetes [1].

Visceral adipose tissue is metabolically active and is associated with altered free-fatty-acid flux, inflammatory signalling, dyslipidaemia, and insulin resistance [2]. Assessment of adiposity benefits from combining anthropometric measures with lipid parameters. The sex-specific VAI combines waist

circumference and BMI with triglyceride and HDL-cholesterol concentrations and was proposed as a surrogate marker of visceral adipose-tissue function and cardiometabolic risk [3].

HOMA-IR is a fasting-state estimate derived from glucose and insulin concentrations and is widely used in epidemiological research, although it is not interchangeable with direct physiological measurements of insulin sensitivity [4,6]. Studying thyroid indices and VAI together may help characterise metabolic associations in people with T2DM. This study therefore evaluated the reported prevalence of subclinical hypothyroidism and the associations of TSH and VAI with HOMA-IR among adults attending PMCH, Patna.

Materials and Methods

Study Design and Setting: A hospital-based, cross-sectional observational study was conducted at Patna Medical College and Hospital (PMCH), Patna, Bihar, India, from April 2025 through April 2026.

Participants and Eligibility: The reported sample comprised 85 eligible adults aged 30–70 years with T2DM. The study specified that diabetes was documented using American Diabetes Association diagnostic criteria, including fasting plasma glucose ≥126 mg/dL or HbA1c ≥6.5%, and that written informed consent was obtained. Exclusions reportedly included established primary thyroid disease or thyroid replacement treatment, pregnancy or lactation, acute infection, severe chronic hepatic or renal impairment, malignancy, and medications known to affect thyroid metabolism.

Clinical and Biochemical Measurements: Demographic and clinical information reportedly included age, sex, duration of diabetes, and medication history. Height and weight were measured to calculate BMI (kg/m²); waist circumference was measured at the midpoint between the lower margin of the last palpable rib and the iliac crest at the end of normal expiration. After a 10–12-hour overnight fast, venous blood was collected for fasting plasma glucose, lipid profile, TSH, FT3, FT4, and fasting insulin. The laboratory methods included an automated chemistry analyser for glucose and lipid testing and chemiluminescent immunoassay for thyroid hormones and insulin.

Definitions and Derived Indices: Subclinical hypothyroidism was defined in the study as TSH >4.5 μIU/mL with FT3 and FT4 within the stated reference intervals (FT3 2.0–4.4 pg/mL; FT4 0.93–1.70 ng/dL). The reported HOMA-IR equation was: fasting insulin (μIU/mL) × fasting plasma glucose (mg/dL) / 405 [4].

VAI was reportedly calculated using sex-specific equations from Amato et al. [3]. For men: [waist circumference / (39.68 + 1.88 × BMI)] × (TG / 1.03) × (1.31 / HDL-C). For women: [waist circumference / (36.58 + 1.89 × BMI)] × (TG / 0.81) × (1.52 / HDL-C). These equations require waist circumference in cm, BMI in kg/m², and TG and HDL-C in mmol/L.

Statistical Analysis: Data were analysed using SPSS version 26.0. Continuous variables were summarised as mean ± standard deviation or median (interquartile range), as appropriate; categorical variables were summarised as counts and percentages. Pearson correlation coefficients evaluated bivariate associations, and multiple linear regression evaluated independent associations with HOMA-IR as the dependent variable. Statistical significance was set at a two-sided $p<0.05$.

Ethics: The study was approved by the Institutional Ethics Committee of PMCH and written informed consent was obtained.

Results

A total of 85 participants were included in the study. Baseline demographic, anthropometric, and biochemical characteristics are summarised in Table 1. The mean age was 51.4 ± 8.2 years, 45 participants (52.9%) were male, and mean diabetes duration was 6.3 ± 3.8 years.

Table 1: Baseline demographic, anthropometric, and biochemical characteristics as reported in the study. Values are mean ± SD unless otherwise indicated.

Variable	Reported value (N=85)
Age, years	51.4 ± 8.2
Male sex, n (%)	45 (52.9%)
Female sex, n (%)	40 (47.1%)
Duration of diabetes, years	6.3 ± 3.8
BMI, kg/m²	26.8 ± 3.4
Waist circumference, cm	92.4 ± 8.6
Fasting plasma glucose, mg/dL	148.6 ± 32.5
HbA1c, %	7.8 ± 1.2
TSH, μIU/mL	3.12 ± 1.84
FT3, pg/mL	2.85 ± 0.52
FT4, ng/dL	1.24 ± 0.28
HOMA-IR	3.64 ± 1.42

Subclinical hypothyroidism was identified in 16 participants (18.8%), while 69 (81.2%) were classified as euthyroid. The group comparisons are presented in Table 2. Participants in the subclinical hypothyroidism group had higher mean fasting glucose, HOMA-IR, and VAI.

Table 2: Reported comparison of clinical and metabolic measures by thyroid-status group. Values are mean ± SD.

Variable	Euthyroid (n=69)	Subclinical hypothyroidism (n=16)	Reported p-value
Age, years	51.1 ± 8.0	52.7 ± 9.1	0.485
Fasting glucose, mg/dL	145.2 ± 30.1	163.3 ± 38.4	0.042
TSH, µIU/mL	2.41 ± 0.82	6.18 ± 1.45	<0.001
HOMA-IR	3.37 ± 1.32	4.82 ± 1.15	<0.001
VAI	2.61 ± 0.74	3.92 ± 0.88	<0.001

As illustrated in Figure 1, the reported mean HOMA-IR and VAI were higher in participants classified as having subclinical hypothyroidism.

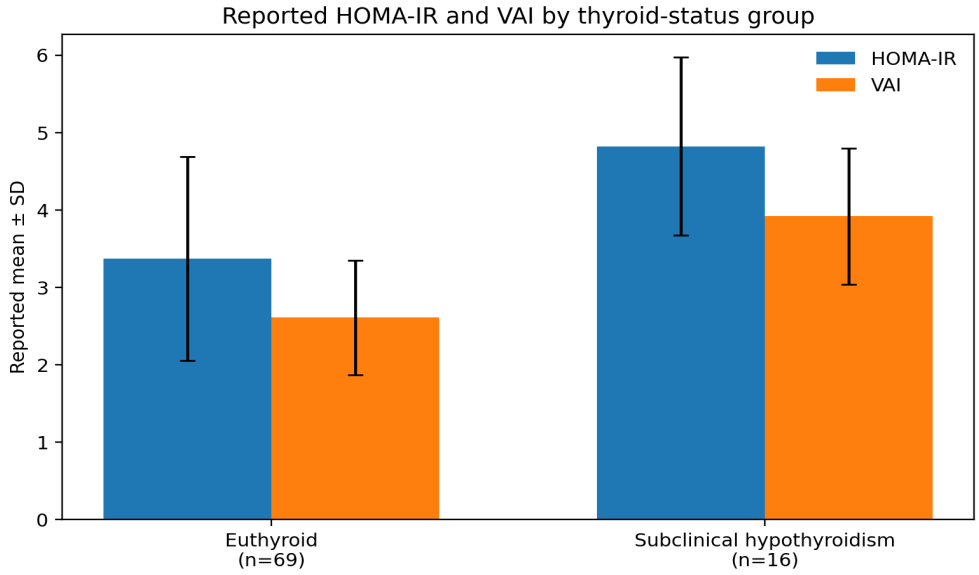


Figure 1: Reported mean HOMA-IR and VAI by thyroid-status group; error bars represent ±1 SD. The two indices have different scales and should be interpreted separately.

Pearson correlation analyses in the study showed positive associations between TSH and HOMA-IR (r=0.428, 95% CI 0.238–0.584), TSH and VAI (r=0.491, 95% CI 0.311–0.637), and VAI and HOMA-IR (r=0.612, 95% CI 0.456–0.731). BMI was also reported to correlate with HOMA-IR (r=0.315, 95% CI 0.111–0.491). The reported coefficients are presented in Table 3 and Figure 2.

Table 3: Reported bivariate Pearson correlations between selected endocrine and metabolic variables.

Variable pair	Pearson r	Reported 95% CI	Reported p-value
TSH vs HOMA-IR	0.428	0.238 to 0.584	<0.001
TSH vs VAI	0.491	0.311 to 0.637	<0.001
VAI vs HOMA-IR	0.612	0.456 to 0.731	<0.001
BMI vs HOMA-IR	0.315	0.111 to 0.491	0.003

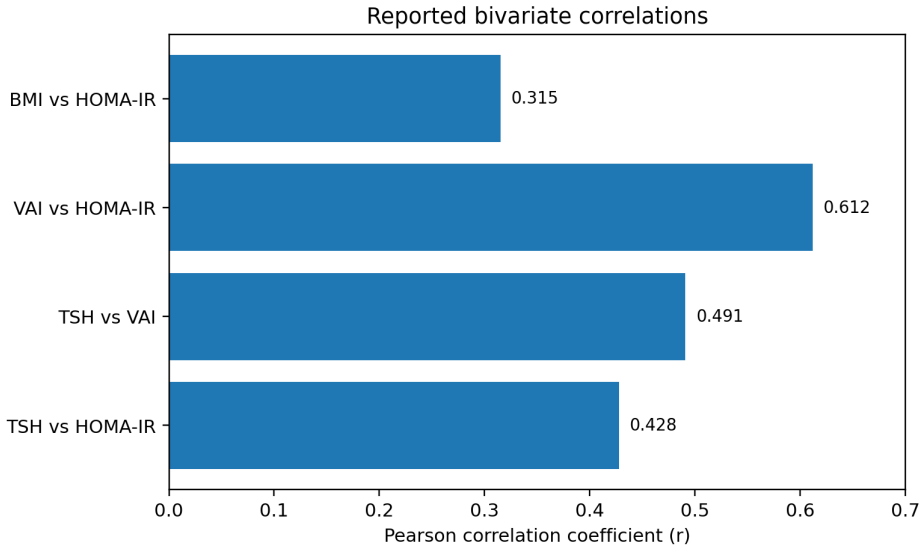


Figure 2: Reported Pearson correlation coefficients for selected variable pairs.

The study reports a multiple linear regression model with HOMA-IR as the dependent variable. After adjustment for age, sex, BMI, and duration of diabetes, VAI (β=0.415, p<0.001) and TSH (β=0.284, p=0.004) were reported as statistically significant correlates; adjusted R^2 was reported as 0.483 (overall model p<0.001).

Discussion

The present study investigated the relationships among thyroid function, insulin resistance, and visceral adiposity in adults with type 2 diabetes mellitus (T2DM) attending Patna Medical College and Hospital (PMCH), Patna. The principal findings were a prevalence of subclinical hypothyroidism of 18.8%, higher mean HOMA-IR and visceral adiposity index (VAI) among participants with subclinical hypothyroidism, and significant positive correlations among thyroid-stimulating hormone (TSH), HOMA-IR, and VAI. Furthermore, TSH and VAI remained statistically significant correlates of HOMA-IR in the reported multivariable analysis. Collectively, these findings highlight the interconnected relationships between thyroid status, adiposity-related metabolic characteristics, and insulin resistance in patients with T2DM.

Thyroid Function and Insulin Resistance: Subclinical hypothyroidism was identified in 16 of the 85 participants (18.8%). The mean HOMA-IR was significantly higher in participants with subclinical hypothyroidism than in euthyroid participants (4.82 ± 1.15 versus 3.37 ± 1.32; $p < 0.001$). In addition, TSH demonstrated a moderate positive correlation with HOMA-IR ($r = 0.428$, $p < 0.001$), indicating that higher TSH concentrations were associated with greater estimated insulin resistance in this cohort.

These findings are consistent with the established physiological relationship between thyroid function and glucose metabolism. Thyroid hormones contribute to the regulation of hepatic glucose production, peripheral glucose utilisation, energy expenditure, and lipid metabolism. Alterations in thyroid function may therefore coexist with changes in insulin sensitivity among individuals with diabetes. Biondi et al. described the close clinical and pathophysiological relationship between thyroid dysfunction and diabetes, highlighting the importance of considering both endocrine systems in metabolic assessment [1].

The higher HOMA-IR observed in the subclinical hypothyroidism group supports the relevance of evaluating thyroid status when characterising metabolic variation in T2DM. HOMA-IR, calculated using fasting glucose and insulin concentrations, is an established surrogate measure used in metabolic research [4,6]. The association observed between TSH and HOMA-IR in the present study suggests that thyroid function may provide complementary information when interpreting insulin resistance in this population.

Relationship Between Thyroid Function and Visceral Adiposity: A significant positive correlation was observed between TSH and VAI ($r = 0.491$, $p < 0.001$). Participants with subclinical hypothyroidism also demonstrated a higher mean VAI than euthyroid participants (3.92 ± 0.88 versus 2.61 ± 0.74; $p < 0.001$). These findings indicate that higher TSH concentrations were associated with a less favourable adiposity-related metabolic profile in the studied cohort.

Thyroid hormones participate in the regulation of energy expenditure and lipid turnover, while adipose tissue is involved in metabolic signalling and lipid storage. The observed relationship between TSH and VAI is therefore consistent with the broader interaction between endocrine regulation and adiposity-related metabolic processes. Evaluating

thyroid parameters alongside adiposity-related indicators may help provide a more comprehensive description of metabolic health in individuals with T2DM.

The VAI was developed as a sex-specific index incorporating body mass index (BMI), waist circumference, triglycerides, and high-density lipoprotein cholesterol (HDL-C) to reflect visceral adipose-tissue function and associated cardiometabolic risk [3]. By incorporating anthropometric and lipid parameters, VAI provides a composite measure that complements BMI in metabolic research. The present findings support further evaluation of the relationship between thyroid function and VAI in populations with T2DM.

Visceral Adiposity Index and Insulin Resistance: The strongest reported bivariate association involving HOMA-IR was observed with VAI ($r = 0.612$, $p < 0.001$). BMI also correlated positively with HOMA-IR ($r = 0.315$, $p = 0.003$), although the correlation coefficient was lower than that observed for VAI. This pattern suggests that the combination of anthropometric and lipid parameters represented by VAI may be particularly relevant to the assessment of insulin resistance in this cohort.

Visceral adipose tissue is metabolically active and is associated with altered free-fatty-acid flux, inflammatory signalling, dyslipidaemia, and impaired insulin action. The relationship between abdominal obesity and metabolic syndrome has been extensively described in the literature [2]. In this context, the positive correlation between VAI and HOMA-IR observed in the present study is consistent with the recognised association between adiposity-related metabolic dysfunction and insulin resistance.

Unlike BMI, which reflects body mass relative to height, VAI combines BMI and waist circumference with lipid measurements. This broader composition may help explain its stronger observed correlation with HOMA-IR in the present sample. The original VAI study proposed the index as a surrogate marker related to visceral adipose-tissue function and cardiometabolic risk [3]. Accordingly, the present findings support investigating VAI as a complementary metabolic indicator in adults with T2DM, alongside conventional anthropometric and biochemical measures.

Independent Associations of TSH and VAI With HOMA-IR: The reported multiple linear regression analysis identified VAI ($\beta = 0.415$, $p < 0.001$) and TSH ($\beta = 0.284$, $p = 0.004$) as statistically significant correlates of HOMA-IR after adjustment for age, sex, BMI, and duration of diabetes. The reported adjusted \(R^2\) was 0.483, indicating that the model accounted for approximately 48.3% of the observed variation in HOMA-IR.

These findings extend the bivariate correlation results by suggesting that TSH and VAI retained statistical associations with HOMA-IR within the reported multivariable model. The results support an integrated approach to studying insulin resistance in T2DM, considering both thyroid-related parameters and adiposity-associated metabolic characteristics. They also provide a foundation for further research examining the contribution of these variables to the variation in insulin resistance among individuals with diabetes.

The interpretation of HOMA-IR requires attention to its calculation and appropriate use in the study population, as discussed by Matthews et al. and Wallace et al. [4,6]. In the present study, the regression findings provide evidence of statistical associations within the analysed cohort. Verification of the complete regression output and model assumptions will help strengthen the interpretation of the reported coefficients, particularly because BMI is also a component of the VAI calculation.

Clinical Implications: The findings have potential relevance for the metabolic assessment of patients with T2DM. The coexistence of subclinical hypothyroidism, higher VAI, and higher HOMA-IR highlights the value of considering endocrine and adiposity-related parameters together when describing metabolic variation in this population.

Thyroid function testing, when clinically indicated, can support the identification and evaluation of thyroid abnormalities. Similarly, waist circumference and lipid measurements are useful components of cardiometabolic assessment, while VAI may offer an additional research measure for examining the relationship between adiposity-related characteristics and insulin resistance. Because VAI is calculated from routinely measured clinical variables, it can be evaluated alongside other indicators without requiring direct imaging of visceral fat.

The American Diabetes Association's Standards of Care provide a framework for the diagnosis and classification of diabetes [5]. Within the broader management of T2DM, the present study adds observational evidence regarding the relationships between thyroid status, adiposity-related metabolic characteristics, and estimated insulin resistance. Further prospective research can determine whether the combined assessment of these variables improves metabolic risk classification or contributes useful information to clinical decision-making.

Strengths and Limitations: A key strength of this study is the simultaneous assessment of thyroid function, insulin resistance, and a composite adiposity index in adults with T2DM. The use of

established methods for calculating HOMA-IR and VAI, together with correlation and multivariable analyses, provides a structured approach to examining relationships among these metabolic domains.

The findings should be interpreted in the context of the study's single-centre, cross-sectional design and sample size of 85 participants. The design supports the identification of associations but does not establish causal relationships or temporal direction. Larger multicentre and prospective studies could build on these findings and examine the clinical significance of the observed relationships.

Future Research Directions: Future research could investigate these associations in larger and more diverse populations with T2DM, using longitudinal designs to assess how changes in thyroid function and adiposity-related parameters relate to changes in insulin resistance over time. Including repeated thyroid-function measurements, detailed lipid profiles, and validated measures of visceral adiposity could help clarify the underlying relationships. Further evaluation of VAI alongside established clinical and biochemical markers may also determine its additional value in metabolic risk assessment.

Conclusion

In this cross-sectional study of adults with type 2 diabetes mellitus, subclinical hypothyroidism was identified in 18.8% of participants and was associated with significantly higher HOMA-IR and visceral adiposity index (VAI) compared with euthyroid status. Thyroid-stimulating hormone (TSH) was positively correlated with both HOMA-IR and VAI, while VAI demonstrated a positive correlation with HOMA-IR. In the reported multivariable analysis, TSH and VAI remained statistically significant correlates of insulin resistance.

These findings highlight the potential relevance of assessing thyroid function alongside anthropometric and lipid-related metabolic indicators when characterising metabolic abnormalities in individuals with T2DM. VAI may provide complementary information to conventional anthropometric measures, while thyroid-function assessment may help identify coexisting thyroid abnormalities when clinically indicated. However, the single-centre design, relatively small sample size, and cross-sectional nature of the study limit generalisability and do not establish causality. Further multicentre, prospective studies are warranted to validate these associations and determine whether combined assessment of thyroid function and VAI provides additional value in metabolic risk assessment.

Declarations

Ethics approval and consent to participate: The study was approved by the Institutional Ethics Committee, PMCH and written informed consent was obtained from all participants.

Data availability: Any supporting data are available from the corresponding author on reasonable request.

Conflicts of interest: The authors declare no competing financial or non-financial interests.

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