



Efficacy of Triglyceride Glucose Index-Neck Circumference (TyG-NC) and Triglyceride Glucose Index Neck-to-Height Ratio (TyG-NHtR) in the Diagnosis of Metabolic Syndrome (MetS)

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ABSTRACT:

Background: Integration of an anthropometric indicator of central adiposity (Neck Circumference, NC, or Neck-to-Height Ratio, NHtR) with a biochemical indicator of Insulin Resistance (IR), the Triglyceride Glucose (TyG) index, is a rational and promising synergistic strategy. The Triglyceride Glucose Index-Neck Circumference (TyG-NC) index, the product of the TyG index and NC, and the Triglyceride Glucose Index Neck-to-Height Ratio (TyG-NHtR) index, the product of the TyG index and NHtR, capture the two fundamental pathologies of Metabolic Syndrome (MetS) in a single metric. These indices provide several benefits, including ease of use, cost-effectiveness, uniform measurements, and suitability for quick screening in settings with limited resources.

Aim: To investigate the efficacy of combining the TyG-NC and TyG-NHtR as a diagnostic tool for MetS.

Materials and Methods: Over the course of eighteen (18) months, this hospital-based, cross-sectional study was conducted on a total of 100 participants, split into two groups: 49 cases (with MetS, as defined by International Diabetes Federation, IDF, criteria) and 51 controls (without MetS). Participants were recruited using a simple random sampling technique, in which patients attending the Department of General Medicine were screened serially against the inclusion and exclusion criteria to build an eligible sampling frame, from which the required number of cases and controls was then selected by simple random sampling (computer-generated random numbers). Fasting blood samples and anthropometric measurements (height, weight, waist circumference, and NC) were taken. The TyG, TyG-NC, and TyG-NHtR indices were calculated according to their respective formulations. **Results:** There was no significant age or gender difference between the groups. Systolic Blood

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Pressure (SBP), Diastolic Blood Pressure (DBP), Triglycerides (TG), and High-Density Lipoprotein (HDL) cholesterol were all significantly different in cases compared to controls. Cases also had significantly larger waist circumference, weight, Body Mass Index (BMI), NC, and NHtR ($p < 0.05$) than controls. No significant difference in fasting glucose levels was observed between the groups. Cases had significantly higher levels of all three indices (TyG, TyG-NC, and TyG-NHtR) than controls ($p < 0.001$), with the largest absolute difference shown by TyG-NC. TyG-NC demonstrated the highest overall diagnostic accuracy (Area Under the Curve, AUC = 0.952; Sensitivity = 91.8%; Specificity = 96.1%; Diagnostic Accuracy = 94%). The TyG index alone also performed well (AUC = 0.917; Sensitivity = 81.6%; Specificity = 92.2%). TyG-NHtR performed the worst (AUC = 0.743; Sensitivity = 81.6%; Specificity = 45.1%). The presence of MetS was positively correlated with all three indices, with TyG-NC showing the strongest correlation ($r = 0.786$, $p < 0.001$); however, on multivariate linear regression, TyG-NHtR showed a negative standardised beta ($\beta = -0.192$, $p = 0.014$), suggesting it is not a robust independent predictor once TyG and TyG-NC are accounted for. **Conclusion:** The composite index TyG-NC performed better than both the standalone TyG index and TyG-NHtR in identifying metabolic syndrome, demonstrating significant diagnostic accuracy and superior predictive power in both genders.

INTRODUCTION:

Metabolic Syndrome (MetS), also known as Reaven syndrome, is a group of interconnected cardiometabolic risk factors, comprising central obesity, dyslipidaemia, hypertension (HTN), and impaired fasting glucose or Insulin Resistance (IR). Although not a disease in itself, MetS describes a cluster of traits associated with a 2-fold increased risk of Cardiovascular Disease (CVD) and a 5-fold or greater risk of Type 2 Diabetes Mellitus (T2DM). Individuals with MetS are 30–40% more likely to develop T2DM, CVD, or both, over 20 years. The majority of MetS-related illness is thought to be primarily driven by obesity and IR.

In low- and middle-income (LMI) nations, MetS is a life-threatening public health issue fuelled by dietary changes, sedentary lifestyles, and urbanisation. MetS is thought to affect roughly one-fourth of adults worldwide, posing significant health, social, and financial challenges. Research has found the age-adjusted prevalence to be more than 25% in urban Indian populations (almost 31% in women and 18.5% in men). A meta-analysis involving 951,083 participants found that all-cause death rates are at least 1.5 times higher in those with MetS.

The International Diabetes Federation (IDF), the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III), and the World Health Organization (WHO) are the main sources of criteria used to operationalise the clinical diagnosis of MetS. While there is consensus on the key components, the diagnostic thresholds vary between them. The IDF considers central obesity a compulsory criterion for diagnosis, together with any three of the five specified components, whereas the WHO requires the presence of IR as a fundamental requirement, accompanied by at least two additional risk factors. Despite their widespread use, these criteria carry conceptual and practical drawbacks, such as ethnicity-specific Waist Circumference (WC) cut-offs and inconsistent measuring procedures. These limitations emphasise the need for more straightforward, standardised surrogate measures capturing the central obesity and IR that form the core pathology of the disorder.

Research has concentrated on finding substitute indicators of IR in response to these difficulties. The Triglyceride-Glucose (TyG) index, computed from Triglycerides (TG) and glucose levels, is a reliable and easily available alternative to the gold-standard hyperinsulinemic-euglycemic clamp. The TyG index has been shown in earlier research to be a reliable indicator of IR, incident T2DM, cardiovascular events, and several other conditions. Its strength lies in the straightforward calculation and integration of two common, inexpensive biological parameters. However, obesity, a significant contributor to MetS, is not captured by the TyG index alone.

Neck Circumference (NC) has gained attention as a trustworthy, easily measurable biomarker of upper-body subcutaneous fat, given its close association with adiposity, IR, and cardiometabolic events. In contrast to waist circumference, its measurement is straightforward, repeatable, affordable, socially less intrusive, and unaffected by daytime variance. Additionally, the Neck-to-Height Ratio (NHtR) has been proposed as a measure of upper-body adiposity that accounts for height disparities, offering a potential advantage over NC alone. NC and NHtR have each demonstrated independent associations with MetS components and cardiovascular risk. Integration of an anthropometric indicator of central adiposity (NC or NHtR) with a biochemical indicator of IR (the TyG index) is a rational and promising synergistic strategy. The Triglyceride Glucose Index-Neck Circumference (TyG-NC) index, the product of the TyG index and NC, and the Triglyceride Glucose Index Neck-to-Height Ratio (TyG-NHtR) index, the product of the TyG index and NHtR, capture the two fundamental

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pathologies of MetS in a single metric. These indices offer several benefits, including ease of use, cost-effectiveness, uniform measurements, and suitability for quick screening in resource-limited settings.

Critical evidence gaps, however, prevent the clinical implementation of the TyG-NC and TyG-NHtR indices, despite their intriguing rationale. Few studies have explicitly assessed these hybrid indices within the same group using conventional MetS criteria, making it difficult to compare their diagnostic efficacy against established indicators and against each other. Additionally, population-specific validation and the development of optimal, sex-specific diagnostic cut-off values are crucial preconditions, as anthropometric index performance is known to vary between demographics. Hence, this study was undertaken to explore the efficacy and relevance of combining the TyG index with NC and NHtR as a diagnostic instrument for MetS.

2. AIM AND OBJECTIVES:

2.1 Aim

To evaluate the diagnostic efficacy of the Triglyceride Glucose Index-Neck Circumference (TyG-NC) and Triglyceride Glucose Index Neck-to-Height Ratio (TyG-NHtR) indices in the diagnosis of Metabolic Syndrome (MetS).

2.2 Objectives

The objectives have been framed using action verbs corresponding to the Analyse, Evaluate and Compare levels of Bloom's Taxonomy of the cognitive domain, so as to reflect measurable, higher-order outcomes of the study:

- To compare the Triglyceride Glucose Index-Neck Circumference (TyG-NC) and Triglyceride Glucose Index Neck-to-Height Ratio (TyG-NHtR) between subjects with and without Metabolic Syndrome (MetS). [Bloom's level: Analyse]
- To determine and compare the diagnostic accuracy of TyG-NC and TyG-NHtR against the Triglyceride-Glucose (TyG) index alone, using Receiver Operating Characteristic (ROC) curve analysis. [Bloom's level: Evaluate]

3. MATERIALS AND METHODS:

3.1 Study Design and setting: This was a hospital-based, cross-sectional study conducted in the Department of General Medicine, Aarupadai Veedu Medical College and Hospital (AVMC), a tertiary care hospital serving a predominantly rural population in Pondicherry, India. The study was carried out over a study duration of eighteen (18) months. All procedures were carried out in compliance with the ethical standards outlined in the Declaration of Helsinki, after obtaining approval from the Institutional Ethics Committee (IEC) and the Institutional Review Board (IRB). Written informed consent was obtained from every participant prior to enrolment.

3.2 Study Participants: Participants were separated into two groups: the case group, comprising patients with a confirmed diagnosis of Metabolic Syndrome (MetS) according to the criteria of the International Diabetes Federation (IDF) Task Force; and the control group, comprising healthy individuals who did not meet the MetS criteria.

3.3 Sample Size Estimation: A sample of 100 participants was included in the study. The estimation was based on the expected sensitivity of the Triglyceride-Glucose (TyG) index in diagnosing Metabolic Syndrome (MetS), reported as 0.86 in prior literature, with a relative precision (d) of 8% and a level of significance of 5%. The sample size was calculated using the standard formula for estimating the sample size for a proportion:

$$n = Z_{1-\alpha/2}^2 \times P(1 - P) / d^2$$

where n = required sample size; $Z_{1-\alpha/2}$ = standard normal deviate at the 95% confidence level (1.96); P = expected prevalence/sensitivity of the Triglyceride-Glucose (TyG) index in diagnosing MetS (0.86); and d = absolute/relative precision (0.08). This yielded a minimum requirement of approximately 91 participants; the final sample was rounded up to 100 participants (49 cases with MetS and 51 controls without MetS) to allow an adequate margin for non-response or incomplete data.

3.4 Sampling Technique and Recruitment: Participants were recruited using a simple random sampling technique. Patients attending the outpatient and inpatient services of the Department of General Medicine, AVMC, were screened serially (i.e., consecutively, in the order in which they presented) against the pre-defined inclusion and exclusion criteria to build an eligible sampling frame for both the case and control groups. From each eligible pool of serially screened patients, the required number of participants was then selected by simple random sampling (using computer-generated random numbers), until the pre-calculated sample size of 49 cases and 51

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controls was reached. This approach—serial screening of consecutive eligible patients followed by simple random selection for final enrolment—was adopted in place of convenience sampling, so as to reduce selection bias while remaining feasible within the 18-month study duration.

3.5 Inclusion Criteria:

- Patients aged greater than 18 years, of either gender (both males and females).
- Patients who provided written informed consent to participate in the study.
- For the case group: patients who satisfied the Metabolic Syndrome (MetS) criteria.
- For the control group: individuals who did not fit the Metabolic Syndrome (MetS) criteria.

3.6 Exclusion Criteria:

- Patients with a Fasting Plasma Glucose (FPG) > 125 mg/dL and a history of diabetes.
- Individuals with plasma triglycerides (TG) > 500 mg/dL and those on lipid-lowering medications.
- Pregnant women.

3.7 Diagnostic Criteria for Metabolic Syndrome: Individuals presenting with any three of the following five risk factors, as defined by the International Diabetes Federation (IDF) Task Force, were classified as having Metabolic Syndrome (MetS) and enrolled in the study as cases:

- Triglycerides (TG): ≥ 150 mg/dL, or a particular lipid abnormality therapy.
- High-Density Lipoprotein (HDL) cholesterol: < 40 mg/dL in men and < 50 mg/dL in women, or under treatment for the lipid imbalance.
- Patients previously diagnosed with Hypertension (HTN), or Systolic Blood Pressure (SBP) > 130 mmHg, or Diastolic Blood Pressure (DBP) > 85 mmHg.
- Fasting Plasma Glucose (FPG) of ≥ 100 mg/dL.
- Waist Circumference (WC): ≥ 80 cm in women and ≥ 94 cm in men.

3.8 Data Collection Methods: Participants who met the eligibility criteria were enrolled in the study after obtaining informed consent and securing approval from the Institutional Ethics Committee (IEC) and the Institutional Review Board (IRB). A structured proforma was used to collect the demographic details (age and gender) and any significant past medical history for each participant.

3.9 Anthropometric Measurements:

- Body weight was recorded using either a digital or mechanical weighing scale with the participant standing erect, and height was measured using a stadiometer with the head positioned in the Frankfurt horizontal plane. The Body Mass Index (BMI) was subsequently calculated as weight (kg) divided by the square of height (m^2).
- Neck Circumference (NC): Participants were instructed to look forward with the head maintained in a neutral alignment while standing or seated upright with relaxed shoulders. Neck Circumference (NC) was measured using a flexible, non-elastic measuring tape positioned horizontally just inferior to the Adam's apple, with the tape encircling the neck at the level of the midpoint of the thyroid anteriorly and the mid-cervical spine posteriorly. Measurements were documented to the nearest 0.5 cm.
- Neck-to-Height Ratio (NHtR) was calculated by dividing the Neck Circumference (NC) by height.

3.10 Blood Pressure Measurement: While measuring the Blood Pressure (BP), the participant was asked to rest for five minutes beforehand, and a sphygmomanometer was used at the time of measurement. To ensure the accuracy of the procedure, participants were advised not to consume tea, coffee, or tobacco products before the measurement.

3.11 Laboratory Measurements: For metabolic analysis, venous blood was collected after an overnight fasting period of at least eight hours had elapsed. Low-Density Lipoprotein (LDL) cholesterol was checked using the direct $MgCl_2$ method, and High-Density Lipoprotein (HDL) cholesterol was calculated by the direct measure method. Total cholesterol was determined using the oxidase-esterase-peroxidase method, and triglycerides (TG) were measured by the enzymatic endpoint method. Fasting blood glucose was measured using the glucose oxidase-peroxidase (GOD-POD) method.

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3.12 Metabolic Syndrome (MetS) Predictors – Calculation of Composite Indices

The following indices were calculated for every participant using the formulae below:

- Triglyceride Glucose (TyG) Index = $\text{Ln} [\text{Fasting Triglycerides (TG, mg/dL)} \times \text{Fasting Glucose (mg/dL)} / 2]$, where Ln denotes the natural logarithm.
- Triglyceride Glucose Index-Neck Circumference (TyG-NC) = TyG index $\times$ Neck Circumference (NC).
- Triglyceride Glucose Index Neck-to-Height Ratio (TyG-NHtR) = TyG index $\times$ (Neck Circumference, NC / Height).

3.13 Outcomes Measured: Sensitivity, specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), Diagnostic Accuracy (DA), and Area Under the Curve (AUC) were used to evaluate how well the Triglyceride Glucose (TyG) index, Triglyceride Glucose Index-Neck Circumference (TyG-NC), and Triglyceride Glucose Index Neck-to-Height Ratio (TyG-NHtR) predict Metabolic Syndrome (MetS).

3.14 Statistical Methods: All data gathered using the structured proforma were entered into a Microsoft Excel worksheet, coded, and transferred into the Statistical Package for the Social Sciences (SPSS, version 23, IBM, Armonk, NY, USA) for analysis. The Kolmogorov-Smirnov test was performed to determine the normality of the data. Descriptive data were presented as numbers, percentages, means, and Standard Deviations (SD). The Mann-Whitney U test was used to compare the means of the groups' metabolic parameters and demographic traits, whereas the Independent t-test was used to compare the anthropometric measurements and the indices (TyG, TyG-NC, and TyG-NHtR). The Chi-Square (χ^2) test was used to compare the categorical data between the groups. The Pearson correlation test was used to correlate the indices with the presence of Metabolic Syndrome (MetS). Receiver Operating Characteristic (ROC) curve and linear regression analyses of the indices with MetS were carried out, with the Area Under the Curve (AUC), optimal cut-off values, sensitivity, specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), and Diagnostic Accuracy (DA) reported for each index. Statistical significance was set at $p \leq 0.05$.

4. RESULTS:

4.1 Demographic and Metabolic Characteristics: The mean age of cases (53.2 ± 13.7 years) was not significantly different from controls (47.9 ± 15.3 years, $p=0.070$). Gender distribution was comparable between groups ($p=1.000$), with males comprising approximately 47% and females 53% in each group. Cases showed significantly higher Systolic Blood Pressure (SBP) (139.6 ± 15.1 vs. 120.8 ± 14.1 mmHg, $p<0.001$), Diastolic Blood Pressure (DBP) (92.4 ± 11.1 vs. 79.8 ± 11.6 mmHg, $p<0.001$), Triglycerides (TG) (163.4 ± 22.4 vs. 117.3 ± 13.9 mg/dL, $p<0.001$), and significantly lower High-Density Lipoprotein (HDL) cholesterol (38.0 ± 7.9 vs. 46.7 ± 15.9 mg/dL, $p=0.003$), compared with controls. Fasting glucose levels did not differ significantly between groups (104.3 ± 12.8 vs. 101.4 ± 10.0 mg/dL, $p=0.138$) (Table 1).

Table 1. Demographic and Metabolic Characteristics of Cases and Controls

Parameter	Controls (n=51)	Cases (n=49)	p-value
Age (years)	47.9 ± 15.3	53.2 ± 13.7	0.070
Male : Female (%)	~47% : 53%	~47% : 53%	1.000
Systolic BP (mmHg)	120.8 ± 14.1	139.6 ± 15.1	<0.001
Diastolic BP (mmHg)	79.8 ± 11.6	92.4 ± 11.1	<0.001
Triglycerides (mg/dL)	117.3 ± 13.9	163.4 ± 22.4	<0.001
HDL cholesterol (mg/dL)	46.7 ± 15.9	38.0 ± 7.9	0.003
Fasting glucose (mg/dL)	101.4 ± 10.0	104.3 ± 12.8	0.138

4.2 Anthropometric Characteristics: Cases had significantly higher Waist Circumference (WC) (96.6 ± 12.5 vs. 86.7 ± 10.7 cm, $p<0.001$), weight (84.6 ± 11.0 vs. 67.1 ± 11.0 kg, $p<0.001$), Body Mass Index (BMI) (32.9 ± 4.9 vs. 26.6 ± 4.5 kg/m², $p<0.001$), Neck Circumference (NC) (38.6 ± 3.8 vs. 31.1 ± 3.0 cm, $p<0.001$), and Neck-to-Height Ratio (NHtR) (0.231 ± 0.034 vs. 0.209 ± 0.032 , $p=0.001$), compared with controls. Height did not differ significantly between groups (160.9 ± 9.9 vs. 159.3 ± 7.9 cm, $p=0.391$) (Table 2).

Table 2. Table 2. Anthropometric Characteristics of Cases and Controls

Parameter	Controls (n=51)	Cases (n=49)	p-value
Waist circumference (cm)	86.7 ± 10.7	96.6 ± 12.5	<0.001
Weight (kg)	67.1 ± 11.0	84.6 ± 11.0	<0.001
BMI (kg/m ²)	26.6 ± 4.5	32.9 ± 4.9	<0.001
Neck circumference (cm)	31.1 ± 3.0	38.6 ± 3.8	<0.001
Neck-to-height ratio	0.209 ± 0.032	0.231 ± 0.034	0.001

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Height (cm)	159.3 ± 7.9	160.9 ± 9.9	0.391 (NS)
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4.3 Insulin Resistance Indices and Correlation with MetS: All three indices were significantly higher in cases compared to controls: the Triglyceride Glucose (TyG) index (9.032 ± 0.194 vs. 8.680 ± 0.155 , $p < 0.001$), the Triglyceride Glucose Index-Neck Circumference (TyG-NC) (348.55 ± 34.51 vs. 269.69 ± 28.01 , $p < 0.001$), and the Triglyceride Glucose Index Neck-to-Height Ratio (TyG-NHtR) (2.083 ± 0.317 vs. 1.812 ± 0.283 , $p < 0.001$). The largest absolute difference between groups was displayed by TyG-NC. On Pearson correlation analysis, all three indices showed significant positive correlations with the presence of Metabolic Syndrome (MetS): TyG-NC demonstrated the strongest correlation ($r = 0.786$, $p < 0.001$), followed by TyG ($r = 0.712$, $p < 0.001$), and TyG-NHtR ($r = 0.416$, $p < 0.001$) (Table 3).

Table 3. Comparison of Insulin Resistance Indices and Correlation with MetS

Index	Controls	Cases	p-value	Correlation (r)
TyG index	8.680 ± 0.155	9.032 ± 0.194	< 0.001	0.712
TyG-NC	269.69 ± 28.01	348.55 ± 34.51	< 0.001	0.786
TyG-NHtR	1.812 ± 0.283	2.083 ± 0.317	< 0.001	0.416

4.4 Diagnostic Performance (ROC Analysis): The TyG-NC composite index showed outstanding discriminative ability with an Area Under the Curve (AUC) of 0.952 (95% Confidence Interval, CI: 0.905–1.000), achieving 91.8% sensitivity, 96.1% specificity, 95.9% Positive Predictive Value (PPV), 92.1% Negative Predictive Value (NPV), and 94.0% Diagnostic Accuracy (DA) at a cut-off of > 311.6 . The TyG index alone demonstrated good performance with an AUC of 0.917 (95% CI: 0.856–0.977), sensitivity 81.6%, specificity 92.2%, PPV 91.7%, NPV 82.1%, and diagnostic accuracy 86.9% at a cut-off of > 8.88 . TyG-NHtR showed fair discriminative ability with an AUC of 0.743 (95% CI: 0.647–0.839), sensitivity 81.6%, specificity 45.1%, PPV 63.1%, NPV 67.1%, and diagnostic accuracy 63.4% at a cut-off of > 1.77 (Table 4).

Table 4. Diagnostic Performance of TyG, TyG-NC and TyG-NHtR (ROC Analysis)

Index	AUC (95% CI)	Cut-off	Sens. (%)	Spec. (%)	PPV (%)	NPV (%)	Accuracy (%)
TyG	0.917 (0.856–0.977)	> 8.88	81.6	92.2	91.7	82.1	86.9
TyG-NC	0.952 (0.905–1.000)	> 311.6	91.8	96.1	95.9	92.1	94.0
TyG-NHtR	0.743 (0.647–0.839)	> 1.77	81.6	45.1	63.1	67.1	63.4

4.5 Gender-Stratified Diagnostic Performance: In males, TyG-NC showed the highest diagnostic accuracy (93.6%) with an AUC of 0.931 (91.3% sensitivity, 95.8% specificity, cut-off > 319.07), followed by TyG (AUC=0.922; 73.9% sensitivity, 91.7% specificity, 82.8% accuracy), and TyG-NHtR (AUC=0.732; 82.6% sensitivity, 33.3% specificity, 58.0% accuracy). In females, TyG-NC again demonstrated outstanding performance with an AUC of 0.970, indicating near-perfect discrimination, with 92.3% sensitivity, 96.3% specificity, and 94.3% diagnostic accuracy at a cut-off of > 311.34 ; this was followed by TyG (AUC=0.914; 88.5% sensitivity, 96.3% specificity, 92.4% accuracy) and TyG-NHtR (AUC=0.758; 80.8% sensitivity, 40.7% specificity, 60.8% accuracy) (Table 5).

Table 5. Gender-Stratified Diagnostic Performance of TyG, TyG-NC and TyG-NHtR

Gender	Index	AUC	Cut-off	Sens. (%)	Spec. (%)	Accuracy (%)
Male	TyG	0.922	> 8.89	73.9	91.7	82.8
Male	TyG-NC	0.931	> 319.07	91.3	95.8	93.6
Male	TyG-NHtR	0.732	> 1.77	82.6	33.3	58.0
Female	TyG	0.914	> 8.91	88.5	96.3	92.4
Female	TyG-NC	0.970	> 311.34	92.3	96.3	94.3
Female	TyG-NHtR	0.758	> 1.74	80.8	40.7	60.8

4.6 Linear Regression Analysis: On multivariate linear regression, TyG-NC showed the strongest independent association with MetS (Standardised $\beta = 0.700$, $p < 0.001$), followed by TyG ($\beta = 0.316$, $p < 0.001$). Notably, TyG-NHtR showed a negative standardised beta ($\beta = -0.192$, $p = 0.014$) in the regression model — in contrast to its positive univariate Pearson correlation with MetS ($r = 0.416$, Table 3) — suggesting that once TyG and TyG-NC are accounted for, TyG-NHtR does not add independent predictive value and its apparent univariate association may largely reflect shared variance with the other two indices (Table 6).

Table 6. Linear Regression Analysis of TyG, TyG-NC and TyG-NHtR with the Presence of Metabolic Syndrome

Variable	Unstd. B	Std. Error	Standardised Beta	t value	p-value
TyG	0.638	0.157	0.316	4.077	< 0.001
TyG-NC	0.007	0.001	0.700	7.358	< 0.001

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TyG-NHtR	-0.294	0.117	-0.192	-2.503	0.014
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4.7 Graphical Summary:

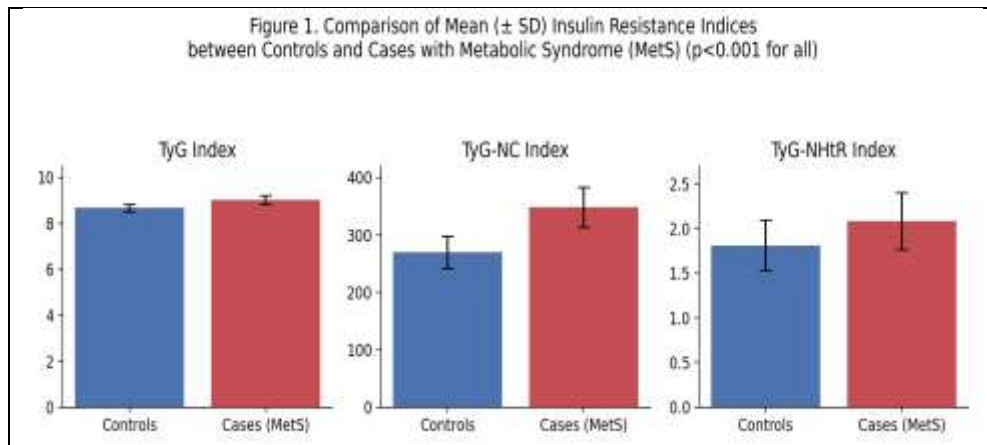


Table 1. Comparison of mean $\pm$ SD values of the TyG index, TyG-NC, and TyG-NHtR in controls versus cases with Metabolic Syndrome (MetS); all three indices were significantly higher in cases ($p < 0.001$).

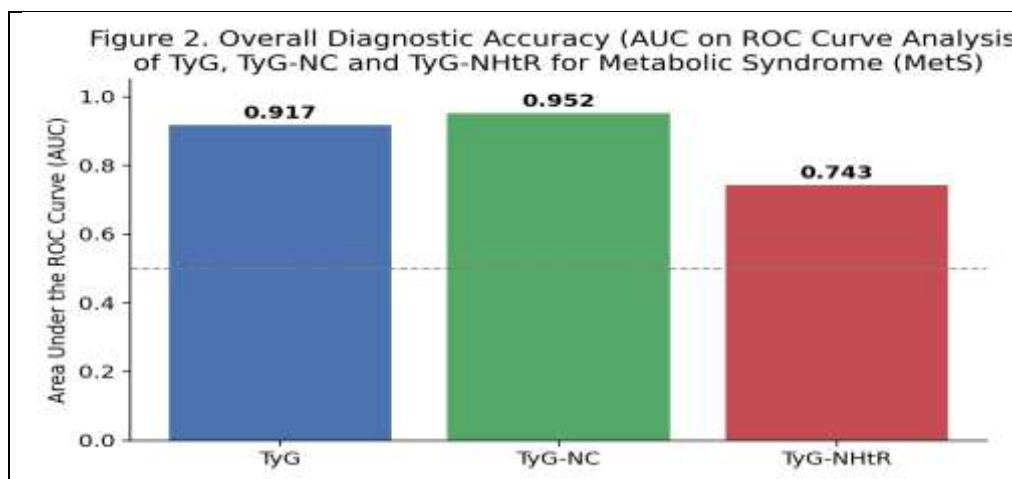


Figure 2. Overall diagnostic accuracy (Area Under the Curve, AUC) of the TyG index, TyG-NC, and TyG-NHtR on Receiver Operating Characteristic (ROC) curve analysis, showing TyG-NC as the best-performing index.

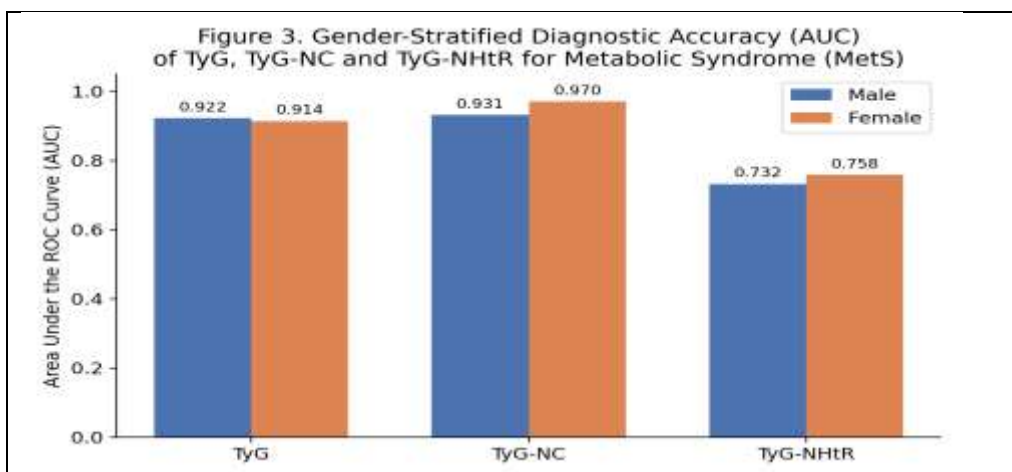


Figure 3. Gender-stratified AUC of the three indices, with TyG-NC demonstrating the highest discriminative ability in both males and females.

5. DISCUSSION:

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The present study demonstrates the diagnostic efficacy of composite indices combining biochemical and anthropometric measurements for identifying Metabolic Syndrome (MetS). Our findings reinforce the strong association between insulin resistance indices and MetS, with all examined indices showing significantly higher levels in the MetS group.

The Triglyceride Glucose (TyG) index demonstrated reliable diagnostic performance (AUC=0.917), consistent with previous literature validating it as a sensitive and specific indicator for MetS screening. This index reflects the core metabolic disturbance of Insulin Resistance (IR) through the integration of triglycerides and glucose, which are routinely available markers. Our optimal cut-off value of >8.88 aligns with findings from Argentine (8.8) and Korean (8.73–8.82) populations, suggesting population-specific applicability.

The most significant finding is the superior diagnostic performance of the Triglyceride Glucose Index-Neck Circumference (TyG-NC) composite index (AUC=0.952), which outperformed both the standalone TyG index and the Triglyceride Glucose Index Neck-to-Height Ratio (TyG-NHtR). This synergistic effect likely results from the combination of two complementary pathways: the TyG index capturing lipid-glucose metabolism and insulin resistance, and Neck Circumference (NC) representing upper-body subcutaneous adiposity. The strong correlation between TyG-NC and MetS ($r=0.786$) and its status as the strongest independent predictor in regression analysis underscore its clinical utility.

On multivariate linear regression, however, TyG-NHtR showed a negative standardised beta ($\beta = -0.192$, $p=0.014$), despite its positive univariate correlation with MetS ($r=0.416$). This divergence suggests that TyG-NHtR's apparent standalone association with MetS is largely attributable to the variance it shares with TyG and TyG-NC, rather than to any independent contribution of its own; once these two indices are accounted for, TyG-NHtR does not meaningfully add to the prediction of MetS. This finding reinforces, from a different analytical angle, the same conclusion drawn from the ROC and correlation analyses — that TyG-NHtR is the weakest of the three indices — and is a nuance worth highlighting explicitly, since a reviewer could otherwise interpret the positive Pearson correlation as being at odds with the regression result.

The superiority of TyG-NC over TyG-NHtR may reflect population-specific body composition differences. The Neck-to-Height Ratio (NHtR) attempts to normalise for height variations but may not adequately capture the absolute visceral and subcutaneous fat depot represented by absolute Neck Circumference (NC). The poor specificity (45.1%) of TyG-NHtR limits its clinical applicability, despite statistical significance in group comparisons.

Gender-stratified analyses revealed consistent superiority of TyG-NC across both males and females, with slightly higher diagnostic accuracy in females (94.3% vs. 93.6%). This consistency suggests that the TyG-NC index represents a robust, sex-independent screening tool for Metabolic Syndrome (MetS).

Limitations of this study include the relatively small sample size from a single institution, potentially limiting generalisability. The cross-sectional design prevents establishment of causality or temporal relationships. Multiple potential confounding factors, such as socioeconomic status, smoking, medications, and dietary patterns, were not analysed. The study was conducted in an Indian population, and findings may vary across different ethnic groups.

Future directions include validation of the TyG-NC index in larger, prospective cohort studies across diverse populations to establish population-specific cut-off values. Investigation of its predictive value for cardiovascular events and incident Type 2 Diabetes Mellitus (T2DM) is warranted. Comparison with imaging-based assessments of adiposity composition would enhance understanding of the mechanistic basis for its superior performance.

6. CONCLUSION:

The composite index TyG-NC demonstrates superior diagnostic accuracy compared to the standalone TyG index and TyG-NHtR for identifying Metabolic Syndrome (MetS). With an Area Under the Curve (AUC) of 0.952, 91.8% sensitivity, 96.1% specificity, and 94% diagnostic accuracy, TyG-NC represents a highly precise, non-invasive, and readily applicable screening tool. The combination of biochemical (TyG) and anthropometric (Neck Circumference, NC) factors improves predictive performance for MetS across both genders. These findings suggest that TyG-NC may be a beneficial supplement for early recognition and risk assessment of MetS in clinical and community settings, particularly in resource-limited contexts, where its simplicity, cost-effectiveness, and accuracy offer substantial advantages over conventional diagnostic approaches.

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