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The Classic TyG Index Outperforms Neck-Based Variants for Detecting Metabolic Syndrome in Metabolic Bariatric Surgery Candidates

Ana L. Alcantara-Diaz

aalcantara@cientifica.edu.pe

Universidad Científica del Sur

Alba Zevallos

Universidad Científica del Sur

Anita P. Llamo-Vilcherrez

OBEMET Center for Obesity and Metabolic Health

Gustavo Salinas-Sedo

Clínica Avendaño

Ruth Reyes-Mercado

University of Navojoa

Kennlly J. Cardoza-Jimenez

OBEMET Center for Obesity and Metabolic Health

Mario B. García-Saavedra

OBEMET Center for Obesity and Metabolic Health

Fabian A. Chavez-Ecos

OBEMET Center for Obesity and Metabolic Health

Pedro J. Ruiz-Pérez

OBEMET Center for Obesity and Metabolic Health

Wah Yang

First Affiliated Hospital of Jinan University

Carlos J. Toro-Huamanchumo

OBEMET Center for Obesity and Metabolic Health

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Abstract

Objective

To compare the diagnostic performance of TyG-NC and TyG-NHtR with the classic TyG index for identifying MetS in bariatric surgery candidates.

Methods

Cross-sectional diagnostic test study using secondary data from adults evaluated at a bariatric clinic. MetS was defined according to Latin American Diabetes Association criteria. Diagnostic accuracy was assessed using AUC-ROC curves with 95% confidence intervals (95%CI). Optimal cut-off points were identified using Liu's method with 1000 bootstrap replications. Associations with MetS were evaluated using Poisson regression models with robust variance to estimate prevalence ratios.

Results

Among 349 adults (67.1% women; mean age 34.9 ± 9.7 years; median BMI 37.3 kg/m²), the classic TyG index evidenced higher discrimination for MetS (AUC 0.86, 95%CI: 0.82–0.90) than TyG-NC (0.72, 95%CI: 0.67–0.77) or TyG-NHtR (0.73, 95%CI: 0.67–0.78). TyG values above 8.8 were strongly associated with MetS (aPR = 3.39, 95%CI: 2.60–4.43), outperforming TyG-NC (aPR = 1.86, 95%CI: 1.47–2.35) and TyG-NHtR (aPR = 1.76, 95% CI: 1.39–2.24). Performance remained consistent across sex-stratified analyses.

Conclusions

In Peruvian bariatric patients, the classic TyG index outperformed its neck-based variants for identifying MetS. When central adiposity and metabolic disturbances are already marked, adding neck circumference may offer limited additional value beyond triglycerides and glucose.

Key points

- The classic TyG index showed greater discrimination capacity for metabolic syndrome than TyG-NC and TyG-NHtR, with consistent results in sex-stratified analyses.
- The classic TyG index showed greater discrimination capacity for metabolic syndrome than TyG-NC and TyG-NHtR, with consistent results in sex-stratified analyses.
- The classic TyG index, being low-cost and routinely available, emerges as a practical screening tool for metabolic syndrome in high-risk bariatric pathways in Latin American settings.

INTRODUCTION

The global prevalence of metabolic syndrome (MetS) varies widely depending on the diagnostic criteria applied, ranging from approximately 12.5% to 31.4% [1]. Nonetheless, it is generally accepted that at least one-quarter of the adult population worldwide meets criteria for MetS [2]. Prevalence also differs by sex and region, with higher estimates reported in men compared to women, and in populations from the Americas and the Eastern Mediterranean compared to those from Africa and parts of Asia [1]. In Peru, estimates range from 10% to 45% in the general population [3], with consistently higher prevalence observed among individuals living with obesity [4]. These patterns highlight the need for early identification of at-risk individuals to mitigate long-term cardiometabolic complications.

While direct measures of insulin resistance are ideal for identifying early metabolic dysfunction, these are expensive and not routinely available in most clinical settings [5, 6]. Consequently, surrogate markers such as the triglyceride-glucose (TyG) index have gained popularity. The TyG index is calculated from fasting glucose and triglycerides and has shown a good correlation with insulin resistance [7] and acceptable performance in detecting MetS [8].

Several adaptations of the TyG index have been proposed to improve its predictive capacity by incorporating anthropometric measures, such as BMI (TyG-BMI), waist circumference (TyG-WC), or waist-to-height ratio (TyG-WHtR) [9–12]. Recently, new variants using neck circumference have emerged —such as the triglyceride and glucose - neck circumference index (TyG-NC) and the triglyceride and glucose - neck circumference to height ratio (TyG-NHtR)—based on the hypothesis that upper-body subcutaneous fat may be more closely related to metabolic risk than abdominal fat [13]. Neck circumference is also simpler to measure and less prone to daily fluctuations compared to waist circumference [14].

Neck circumference is easier to standardize, and less intrusive; moreover, it is not influenced by the time of day, food intake, or abdominal distension [15, 16]. This approach may be particularly relevant in high-risk populations such as adults with obesity undergoing metabolic bariatric surgery (MBS) assessment, where subtle differences in fat distribution and metabolic dysfunction remain clinically important [17, 18]. In addition, little is known about their diagnostic performance in Latin American populations, which have particular and independent anthropometric characteristics, lifestyles, and socio-demographic factors [19, 20].

In this study, we aimed to compare the diagnostic performance of TyG-NC and TyG-NHtR against the classic TyG index and its individual components for identifying MetS in a Peruvian cohort of adults with obesity undergoing MBS evaluation.

METHODS

Study design

We conducted a cross-sectional analytical study with a diagnostic test approach, using secondary data from patients who attended a bariatric center in Lima, Peru, between 2016 and 2020.

Population and procedures

Our study population consisted of adults aged 18 to 59 years who were candidates for MBS, with a body mass index (BMI) ≥ 30 kg/m². We included individuals with sufficient anthropometric data to calculate TyG-NC and TyG-NHtR. We excluded patients with a history of thyroid disease; those who tested positive for hepatitis C antibodies or hepatitis B surface antigen; and those with a history of gout, chronic kidney disease, cerebrovascular accident, myocardial infarction, or angina.

It should be noted that anthropometric measurements in the clinic were taken by trained personnel following a protocol based on the recommendations of the World Health Organization [21, 22]. Waist and neck circumferences were recorded in centimeters (cm) using a non-elastic measuring tape, with anatomical landmarks identified at the midpoint between the last rib and the iliac crest for waist circumference, and the mid-cervical level for neck circumference. Body weight was assessed using either a TANITA TBF-310 or SECA 514m Medical Body Composition Analyzer, and height was measured using a portable SECA stadiometer. All equipment was regularly calibrated in accordance with institutional protocols. Laboratory variables were obtained after a minimum fasting period of eight hours, and analyses were performed using the Cobas 6000 Module C501 analyzer.

Study variables

Definition of MetS

MetS was defined in accordance with the Latin American Diabetes Association (ALAD) criteria [23], which require 1) a waist circumference ≥ 94 cm in men and ≥ 88 cm in women, plus; 2) least two of the following four conditions: TG ≥ 150 mg/dL (or on specific lipid-lowering therapy), HDL-cholesterol < 40 mg/dL in men or < 50 mg/dL in women (or on treatment affecting HDL), systolic blood pressure (SBP) ≥ 130 mmHg and/or diastolic blood pressure (DBP) ≥ 85 mmHg, abnormal fasting glucose (≥ 100 mg/dL), or diabetes, or diabetes. For analysis, MetS status was dichotomised (yes/no).

TyG, TyG-NC and TyG-NHtR indices

We calculated the following indirect indices for the detection of MetS: TyG-NC: TyG × NC [13], and TyG-NHtR: TyG × NHtR [13]. For their individual components, we used the formulas: TyG index: Ln [TG (mg/dL) × fasting glucose (mg/dL) / 2] [24], and NHtR: neck circumference (cm) / height (cm) [13].

Additional covariates

We also recorded: 1) Sociodemographic data: age (years), sex (male, female); 2) Medical history: hypertension (yes, no), type 2 diabetes mellitus (yes, no), alcohol use (yes, no), tobacco use (yes, no); 3) Anthropometric measures: weight (kg), height (cm), BMI (kg/m²), neck circumference (cm), waist circumference (cm); 4) Laboratory variables: fasting plasma glucose (mg/dL), fasting insulin (μU/mL),

homeostasis model assessment of insulin resistance (HOMA-IR), aspartate aminotransferase (AST) (U/L), alanine aminotransferase (ALT) (U/L), total cholesterol (mg/dL), HDL-cholesterol (mg/dL), LDL-cholesterol (mg/dL); and 5) Vital signs: SBP (mmHg) and DBP (mmHg).

Statistical analysis

We described continuous variables using means and standard deviations or medians and interquartile ranges, after checking normality assumptions. Categorical variables were presented as absolute and relative frequencies. For bivariate comparisons, continuous variables were examined using Student's t-test or the Mann–Whitney U test, depending on the distribution of the data. Categorical variables were assessed using the Chi-square test or Fisher's exact test, depending on whether the expected cell counts were greater than 5.

To assess the ability of the TyG index and its anthropometric variants (TyG-NC and TyG-NHtR) to discriminate MetS, we constructed Receiver Operating Characteristic (ROC) curves and calculated the area under the curve (AUC) with 95% confidence intervals (95% CIs). Analyses were stratified by sex. We also identified the best cutoff point for each marker using Liu's method, and estimated 95% CIs for sensitivity (Se), specificity (Sp), positive predictive value (PPV), negative predictive value (NPV), and likelihood ratios (LR + and LR-).

Using the previously identified optimal cut-off points, we fitted generalized linear models (GLMs) with a Poisson distribution, log link function, and robust variance estimators to assess the association between each dichotomized marker and MetS, both in the overall population and stratified by sex. Models were adjusted for age, sex, alcohol consumption, tobacco use, and ALT—covariates selected a priori based on epidemiological relevance. BMI was not included due to theoretical and statistical collinearity (variance inflation factor [VIF] > 10) with MetS components and neck circumference–derived indices.

As an additional exploratory step, we employed restricted cubic splines (with four knots) to evaluate potential non-linear relationships between these TyG-based indices and MetS. These spline models were adjusted for the same covariates (age, sex, alcohol, tobacco, ALT) and were fitted in R using the *'rms'* package. The spline curves were referenced to the median value of the first quartile (Q1) of each TyG-based index. This approach helped visualize whether the association plateaued or changed slope at higher index levels.

All statistical analyses were performed in Stata v18.5 (StataCorp, TX, USA) and R software (v4.0.4, R Foundation for Statistical Computing, Vienna, Austria). The level of significance was set at $p < 0.05$, and all estimates were presented with their 95% CIs.

Ethics

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Universidad de San Martín de Porres (No. 1261-2022-CIEI-FMH-USMP). The study used secondary data from anonymized clinical records, with no direct patient contact or intervention. Data was handled confidentially by the research team.

RESULTS

General characteristics of the study population

A total of 349 adults seeking MBS were included. The mean age was 34.9 ± 9.7 years, 67.1% (n = 234) were female, the median BMI was 37.3 [IQR: 33.9–40.8], and 55.6% (n = 194) had MetS (Supplementary Table 1). The mean values of TyG (9.1 ± 0.5 vs. 8.5 ± 0.3, $p < 0.001$), TyG-NC (385.1 ± 62.9 vs. 339.4 ± 47.3, $p < 0.001$) and TyG-NHtR (2.3 ± 0.3 vs. 2.1 ± 0.3, $p < 0.001$) were significantly higher in the MetS group (Table 1).

Table 1
General characteristics according to the presence of MetS (n = 349).

Characteristics	**MetS**		
	Yes (n = 194)	**No (n = 155)**	***p***
Age (years)	37.2 ± 9.3	32.1 ± 9.4	< 0.001*
Sex			0.245**
Male	69 (60.0)	46 (40.0)	
Female	125 (53.4)	109 (46.6)	
Alcohol use			0.162**
Yes	120 (52.9)	107 (47.1)	
No	74 (60.7)	48 (39.3)	
Tobacco use			0.697**
Yes	42 (46.2)	49 (53.9)	
No	145 (56.2)	113 (43.8)	
Hypertension			< 0.001**
Yes	52 (81.2)	12 (18.8)	
No	142 (49.8)	143 (50.2)	
Type 2 diabetes mellitus			< 0.001†
Yes	22 (95.6)	1 (4.4)	
No	172 (52.8)	154 (47.2)	
Weight (kg)	101 [92.3–118.6]	96.2 [86.1–107.2]	0.002‡
Height (cm)	1.7 ± 0.1	1.6 ± 0.1	0.347*
BMI (kg/m^2)	38.3 [35.1–42.5]	35.9 [33.6–40.1]	0.001‡
Neck circumference (cm)	42.3 ± 6.0	40.0 ± 5.1	< 0.001*
Waist circumference (cm)	117.6 ± 16.3	110.7 ± 15.2	< 0.001*
Fasting plasma glucose (mg/dL)	96 [89–102]	89 [84–93]	< 0.001‡
Insulin (uU/mL)	26.0 [19–38.8]	18.9 [13.6–26.2]	< 0.001‡

Characteristics	MetS		
	Yes (n = 194)	No (n = 155)	*p*
Total Cholesterol (mg/dL)	197.4 ± 38.8	180.9 ± 35.0	< 0.001*
HDL Cholesterol (mg/dL)	40.1 ± 9.1	48.7 ± 10.3	< 0.001*
LDL Cholesterol (mg/dL)	117.7 ± 33.5	109.5 ± 30.9	0.019*
Triglycerides (mg/dL)	183.5 [142–235]	111 [84–137]	< 0.001‡
AST (U/L)	25 [18–40]	21 [16–30]	0.003‡
ALT (U/L)	36 [22–60]	28 [17.9–46]	< 0.001‡
SBP (mmHg)	123.9 ± 13.4	115.4 ± 10.1	< 0.001*
DBP (mmHg)	80.4 ± 9.2	75.5 ± 7.6	< 0.001*
HOMA-IR	6.1 [4.4–9.3]	4.2 [2.9–5.8]	< 0.001‡
TyG index	9.1 ± 0.5	8.5 ± 0.3	< 0.001*
TyG-NC	385.1 ± 62.8	339.4 ± 47.3	< 0.001*
TyG-NHtR	2.3 ± 0.4	2.1 ± 0.3	< 0.001*

MetS: metabolic syndrome; **BMI**: body mass index; **SBP**: systolic blood pressure; **DBP**: diastolic blood pressure; **AST**: aspartate aminotransferase; **ALT**: alanine aminotransferase; **HOMA-IR**: homeostasis model assessment of insulin resistance, **TyG**: triglyceride-glucose index; **TyG-NC**: triglyceride-glucose index combined with neck circumference; **TyG-NHtR**: triglyceride-glucose index combined with neck-to-height ratio.

Mean ± standard deviation

Median [P25 - P75]

* Student's t-test for independent samples

** Chi-square test

† Fisher's exact test

‡ Mann–Whitney U test

Diagnostic performance of TyG-NC and TyG-NHtR for MetS

Table 2 and Fig. 1 show the AUC values and cut-offs for TyG, TyG-NC and TyG-NHtR, along with Se, Sp, PPV, NPV, LR+, and LR−. In the overall sample, the AUCs for TyG, TyG-NC and TyG-NHtR were 0.86 (95% CI: 0.82–0.90), 0.72 (95% CI: 0.67–0.77) and 0.73 (95% CI: 0.67 − 0.78), respectively. After stratifying by sex, performance for TyG-NC and TyG-NHtR was slightly better in males (AUC 0.76 vs 0.74 and 0.76 vs 0.72, respectively), whereas the performance of TyG was similar in both sexes (AUC 0.86). The cut-off points for TyG, TyG-NC and TyG-NHtR in the overall sample were 8.8 (95% CI: 8.7–8.9), 345.9 (95% CI: 319.8–371.0) and 2.2 (95% CI: 2.1 − 2.3), respectively.

Table 2. Diagnostic performance of TyG, TyG-NC and TyG-NHtR for metabolic syndrome, stratified by sex.

Characteristics		AUC (95% CI)	Cutoff (95% CI)*	Se (%)	Sp (%)	PPV (%)	NPV (%)	LR +	LR -
TyG									
All sample		0.86 (0.82–0.90)	8.8 (8.7–8.9)	77.3	86.5	87.7	75.3	5.7	0.3
Sex	**Male**	0.86 (0.78–0.93)	8.9 (8.7–9.0)	84.1	80.4	86.6	77.1	4.3	0.2
	Female	0.86 (0.81–0.91)	8.8 (8.7–8.9)	73.6	89.0	88.5	74.6	6.7	0.3
TyG-NC									
All sample		0.72 (0.67–0.77)	345.9 (319.8–371.0)	71.1	60.0	69.0	62.4	1.8	0.5
Sex	**Male**	0.76 (0.68–0.85)	415.5 (389.4–441.6)	95.7	17.4	63.5	72.7	1.2	17.4
	Female	0.74 (0.68–0.80)	329.5 (313.0–346.0)	57.6	78.0	75.0	61.6	2.2	0.5
TyG-NHtR									
All sample		0.73 (0.67–0.78)	2.2 (2.1–2.3)	73.2	57.4	68.3	63.1	1.7	0.5
Sex	**Male**	0.76 (0.68–0.85)	2.4 (2.3–2.6)	91.3	34.8	67.7	72.7	1.4	0.3
	Female	0.72 (0.66–0.79)	2.1 (2.0–2.2)	63.2	67.0	68.7	61.3	1.9	0.5

*Confidence intervals estimated using bootstrap with 1,000 replications.

MetS: metabolic syndrome; **TyG**: triglyceride-glucose index; **TyG-NC**: triglyceride-glucose index with neck circumference; **TyG-NHtR**: triglyceride-glucose index with neck-to-height ratio; **AUC**: area under the curve; **CI**: confidence interval; **Se**: sensitivity; **Sp**: specificity; **PPV**: positive predictive value; **NPV**: negative predictive value; **LR+**: positive likelihood ratio; **LR–**: negative likelihood ratio.

Association between the best cut-off points of TyG, TyG-NC and TyG-NHtR with MetS

Table 3 presents the crude and adjusted regression models. In the crude model, values above the respective cut-offs for TyG (cPR = 3.55, 95% CI: 2.73–4.61, p < 0.001), TyG-NC (cPR = 1.84, 95% CI: 1.46–2.30, p < 0.001) and TyG-NHtR (cPR = 1.85, 95% CI: 1.46–2.34, p < 0.001) were associated with MetS. After adjusting for confounders, the association remained significant for all of them (TyG: aPR = 3.39, 95% CI: 2.60–4.43, p < 0.001; TyG-NC: aPR = 1.86, 95% CI: 1.47–2.35, p < 0.001; TyG-NHtR: aPR = 1.76, 95% CI: 1.39–2.24, p < 0.001). The results remained significant in sex-stratified analyses.

Table 3. Association between the optimal cutoff point of the markers (TyG, TyG-NC and TyG-NHtR) and MetS, stratified by sex.

Characteristics		Crude model			Adjusted model		
		cPR	95% CI	*p*	aPR	95% CI	*p*
TyG							
All sample		3.55	2.73–4.62	< 0.001	3.39†	2.60–4.43	< 0.001
Sex	**Male**	3.43	2.12–5.55	< 0.001	3.36‡	2.10–5.37	< 0.001
	Female	3.49	2.57–4.72	< 0.001	3.20‡	2.33–4.40	< 0.001
TyG-NC							
All sample		1.84	1.46–2.30	< 0.001	1.86†	1.47–2.35	< 0.001
Sex	**Male**	2.05	1.46–2.86	< 0.001	2.02‡	1.44–2.84	< 0.001
	Female	2.15	1.59–2.92	< 0.001	1.91‡	1.41–2.59	< 0.001
TyG-NHtR							
All sample		1.85	1.46–2.34	< 0.001	1.76†	1.39–2.24	< 0.001
Sex	**Male**	1.91	1.36–2.67	< 0.001	1.91‡	1.36–2.67	< 0.001
	Female	1.78	1.37–2.30	< 0.001	1.61‡	1.24–2.09	< 0.001

MetS: metabolic syndrome; **TyG**: triglyceride-glucose index; **TyG-NC**: triglyceride-glucose index with neck circumference; **TyG-NHtR**: triglyceride-glucose index with neck-to-height ratio; **cPR**: crude prevalence ratio; **aPR**: adjusted prevalence ratio; **CI**: confidence interval.

†Adjusted for: age, sex, alcohol use, tobacco use, and alanine aminotransferase (ALT).

‡ Adjusted for: age, alcohol use, tobacco use, and alanine aminotransferase (ALT).

Figure 2 shows the adjusted prevalence ratios derived from restricted cubic spline models evaluating the continuous association of TyG, TyG-NC, and TyG-NHtR with MetS. TyG exhibited a non-linear relationship, with a steep increase in PRs at lower values that plateaued at higher concentrations (p for non-linearity = 0.001). In contrast, both TyG-NC and TyG-NHtR demonstrated linear dose–response associations across the distribution, with no evidence of non-linearity (p = 0.337 and p = 0.373, respectively).

DISCUSSION

In this cohort of Peruvian adults undergoing MBS, the classic TyG index out-performed the two neck-circumference-based derivatives (TyG-NC and TyG-NHtR) for detecting MetS. Although both neck-based variants showed acceptable accuracy, neither eclipsed the original TyG formula, indicating that the metabolic perturbations reflected by fasting triglycerides and glucose alone are sufficient to discriminate MetS in this high-risk group.

Prior research has described the utility of the TyG index as a surrogate marker for insulin resistance and metabolic dysfunction across diverse populations [8]. Neck circumference, meanwhile, has been proposed as a practical anthropometric marker of cardiometabolic risk [15, 17, 18, 25]. In some population—typically Caucasian adults [13] and children with overweight or obesity [26–29]—neck circumference has been linked with an improved diagnostic performance, presumably because upper-body subcutaneous fat exerts a disproportionate influence on insulin resistance In MBS candidates, however, metabolic abnormalities are already pronounced; consequently, neck circumference adds little incremental value beyond the biochemical information captured by triglycerides and glucose [13]. Neck-based indices may prove more useful in individuals nearer the overweight or normal-weight range, where subtle differences in fat distribution might be still discriminative [9, 13, 30]. Moreover, waist circumference remains the core anthropometric criterion for MetS, so incorporating a second girth measure can be redundant when a high BMI (class II–III in ~ 70% of our sample) already signals substantial dysmetabolism.

Population-specific body-composition patterns could also explain our findings. Latin-American populations have been shown to accumulate more visceral and truncal adiposity at similar BMI values [31]. This characteristic may diminish the incremental utility of upper-body anthropometric markers, such as neck circumference, since abdominal fat is already disproportionately elevated. Such ethnic, genetic, lifestyle, and early-life nutritional differences—particularly variations in trunk-to-leg length ratio [32, 33]—shape regional patterns of adiposity.

From a clinical perspective, the classic TyG index is inexpensive, relies solely on routine fasting lipids and glucose, and can be automated, making it attractive for rapid screening in bariatric pathways. Accurate neck-circumference measurement can be challenging in severe obesity, where anatomical landmarks are difficult to identify, potentially reducing the reliability of this measure [34]. In Latin America, where cardiometabolic risk is high [35] and health-care resources may be constrained [36], the TyG index could offer a cost-effective option for identifying high-risk bariatric patients. Emerging evidence also links elevated pre-operative TyG levels to a higher risk of adverse cardiovascular events in non-cardiac surgeries, underscoring its relevance in peri-operative risk stratification [37]. Integrating TyG into pre-operative protocols could streamline metabolic assessment and guide early interventions, particularly in high-volume surgical centers. Further studies are needed to establish standardized cut-off points and confirm its prognostic value in diverse populations.

Strengths of this study include a well-characterized bariatric cohort, sex-stratified receiver-operating-characteristic analysis, and robust Poisson regression. Additionally, it is one of the few studies worldwide—and the only one in Latin America—to evaluate neck-circumference–based TyG variants in a MBS cohort. However, some limitations must be acknowledged. First, the cross-sectional design precludes causal inference and cannot evaluate long-term prognostic value. Second, participants were recruited from a single private clinic, limiting external validity—particularly to public-sector or lower-BMI populations. Third, although neck circumference measurements were performed by trained personnel, real-world clinical settings may introduce measurement variability. In individuals with high BMI, difficulty in locating anatomical landmarks can hinder precise measurements, limiting the reliability and clinical applicability of this parameter [34, 38].

In conclusion, among Peruvian adults undergoing MBS, the classic TyG index outperformed TyG-NC and TyG-NHtR for MetS detection. These findings imply that, at higher BMI levels, biochemical markers of dyslipidemia and glycemic disturbance may fully capture the metabolic burden, rendering neck-based refinements redundant. Prospective studies should confirm whether this pattern holds in less-severe obesity, across diverse Latin-American populations, and for predicting long-term cardiometabolic outcomes. If validated, integrating the TyG index into pre-operative protocols could streamline metabolic screening while conserving clinical resources.

DECLARATIONS

Author's contribution:

Ana L. Alcantara-Diaz: Conceptualization, Investigation, Writing - Original Draft.

Alba Zevallos: Conceptualization, Investigation, Writing - Original Draft.

Anita P. Llamo-Vilcherrez: Conceptualization, Investigation, Writing - Original Draft.

Gustavo Salinas-Sedo: Conceptualization, Investigation, Writing - Review & Editing.

Ruth Reyes-Mercado: Investigation, Writing - Original Draft, Writing - Review & Editing.

Kennlly J. Cardoza-Jimenez: Conceptualization, Investigation, Writing - Original Draft, Writing - Review & Editing.

Mario B. García-Saavedra: Investigation, Writing - Original Draft, Writing - Review & Editing.

Fabian A. Chavez-Ecos: Investigation, Writing - Original Draft, Writing - Review & Editing.

Pedro J. Ruiz-Pérez: Investigation, Writing - Original Draft, Writing - Review & Editing.

Wah Yang: Investigation, Writing - Original Draft, Writing - Review & Editing.

Carlos J. Toro-Huamanchumo: Conceptualization, Methodology, Supervision, Writing - Review & Editing.

Competing interests:

None to declare.

Human Ethics and Consent to Participate:

The study was conducted following the ethical standards of research involving human participants. As this was a retrospective analysis of anonymized secondary data, informed consent was waived by the Institutional Review Board.

Ethical Approval:

The study was approved by the Ethics Committee of the Universidad de San Martín de Porres (No. 1261-2022-CIEI-FMH-USMP).

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Consent for publication:

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Data availability:

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Figures

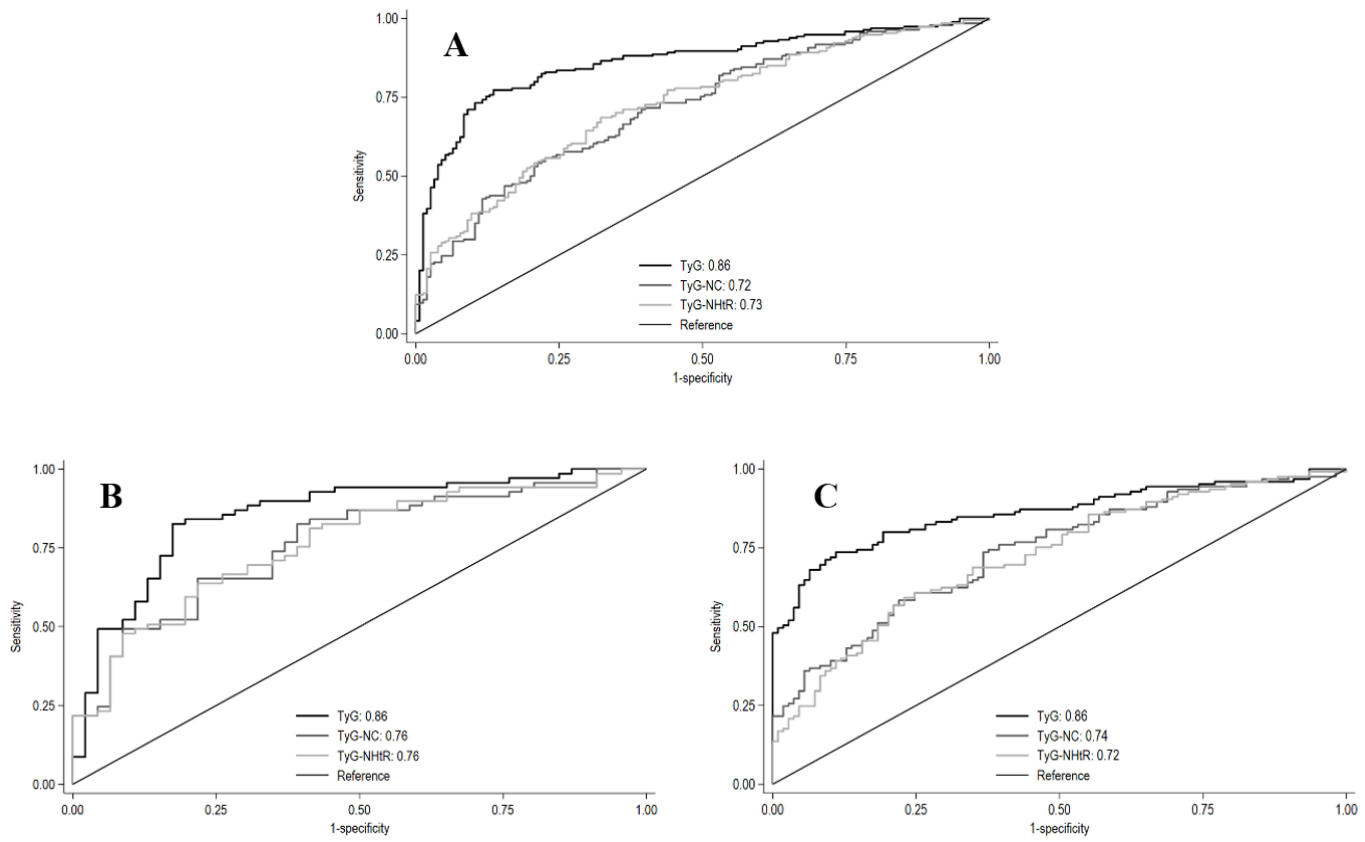


Figure 1

ROC AUC for (A) Total sample, (B) Men, and (C) Women.

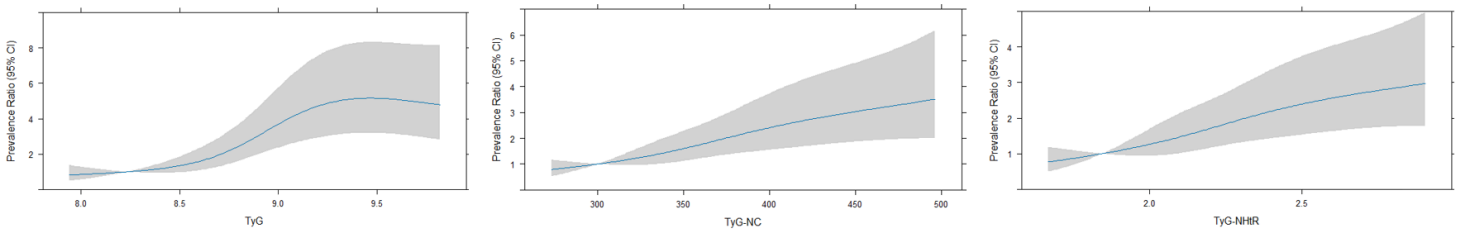


Figure 2

Association between TyG-based indices and metabolic syndrome using multivariable Poisson models with restricted cubic splines. Adjusted prevalence ratios and 95% CIs are shown for (A) TyG, (B) TyG-NC, and (C) TyG-NHtR. Curves are centered at the median value of the first quartile (Q1) for each index. Models were adjusted for age, sex, alcohol use, tobacco use, and alanine aminotransferase (ALT).

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