

Research Article

Metabolic Syndrome in Cuba: Comparison ATP III vs Triglyceride/Glucose Index (TyG ≥ 8.5)José Antonio Alonso Viamonte^{1*}  and María Caridad Rodríguez Pérez²¹Specialist in General Integral Medicine, René Vallejo Ortiz Polyclinic, Matanzas, Cuba²Bachelor's in health technologies, Pharmaceutical Services Profile, Pedro Pablo Rivera Cue Polyclinic, Matanzas, Cuba**Corresponding Author:** José Antonio Alonso Viamonte, Specialist in General Integral Medicine, René Vallejo Ortiz Polyclinic, Matanzas, Cuba.**Received:**  2026 July 13**Accepted:**  2026 July 24**Published:**  2026 July 31**Abstract****Introduction:**

Metabolic syndrome (MS) is increasingly recognized as a major health challenge in Cuba and worldwide. Its strong links with type 2 diabetes, cardiovascular disease, and premature mortality are well established. The condition often progresses silently, with few early warning signs, while multiple metabolic disturbances interact in complex ways. This hidden course makes early recognition difficult and highlights the need for diagnostic tools that are both sensitive and practical. The triglyceride/glucose index (TyG) has emerged as a simple, reproducible marker of insulin resistance and may identify individuals at risk earlier than ATP III criteria.

Objectives: To compare the diagnostic performance of ATP III criteria and the TyG index (≥ 8.5) in a Cuban cohort, and to assess whether TyG adds value in early detection and risk stratification of metabolic syndrome.

Methods: We conducted an observational, cross sectional study among adults receiving primary health care in Cuba. Two diagnostic frameworks were applied: ATP III criteria (≥ 3 components) and TyG ≥ 8.5 . Anthropometric measures, blood pressure, and biochemical parameters were collected. HDL cholesterol was estimated using equations due to laboratory constraints. Analyses were stratified by sex, and statistical procedures included chi square tests, Student's *t* tests, and correlation analyses.

Results: ATP III identified 45% of patients, whereas TyG ≥ 8.5 detected 86.9%. TyG corrected the sex related bias observed with ATP III, producing a more balanced distribution between men and women. Combined criteria improved specificity, while the unified approach achieved the highest sensitivity (87%) with acceptable specificity (69%). Obesity was a major contributor (25.3%), and 32.3% were overweight. Even among those with normal BMI (35.4%), metabolic changes were evident.

Conclusions: The TyG index proved to be a practical, inexpensive diagnostic option. Applied in Cuban primary care, it could strengthen prevention, reduce cardiometabolic risk, and support timely management of metabolic syndrome.

Keywords: Metabolic syndrome, Triglyceride/glucose index (TyG), Insulin resistance, prevalence, Cuba, Cardiometabolic risk

1. Introduction

Metabolic syndrome (MS) is currently recognized as one of the major public health challenges, both in Cuba and worldwide. Its growing burden of negative consequences has positioned it as a global phenomenon, with direct impact on quality of life and disease load in communities, our own being a clear example. Given its presentation with few initial symptoms, physical appearance often plays a key role,

reinforcing the need for more effective preventive measures and for low-cost, easy-to-apply tools capable of anticipating risks before they manifest clinically. The presence of this "deadly quartet" significantly increases the risk of developing type 2 diabetes and atherogenic cardiovascular disease, two of the leading causes of morbidity and mortality in the general population. The triglyceride-glucose index (TyG) has emerged as a reliable instrument for diagnosing insulin

resistance in individuals with dysglycemia.

Both international and local studies have demonstrated its ability to predict all-cause mortality, incident hypertension, renal disease, and neurological disorders, strengthening its clinical value as a supportive tool alongside classical criterion. These findings highlight the need to complement established frameworks such as ATP III with more dynamic and accessible indicators. In the Cuban context, Díaz Díaz, O. et al. demonstrated the importance of adapting international criteria to the country's epidemiological and technological reality, where laboratory limitations demand viable diagnostic alternatives [1]. Internationally, similar investigations have been conducted, such as the study by Afshar M. et al. (2025) in Iran. Building on this foundation, the present study aimed to evaluate the prevalence of metabolic syndrome in a Cuban sample of 2000 patients, applying ATP III criteria and the TyG index (≥ 8.5) [2]. The objective was to provide evidence that strengthens clinical practice and prevention strategies in our country, particularly from the perspective of primary health care.

2. Materials and Methods

A cross-sectional analytical study was conducted including 2000 patients aged 18 years or older from Primary Health Care in Cuba. To validate the diagnosis of metabolic syndrome, two complementary tools were applied: the ATP III criteria (≥ 3 components) and the triglyceride-glucose index (TyG ≥ 8.5), used as an additional marker of insulin resistance in individuals with dysglycemia. Due to laboratory limitations, HDL cholesterol was estimated using mathematical equations. The following elements were also examined: personal and family history, habits and lifestyle, anthropometric measurements (weight, height, BMI, abdominal circumference), and blood pressure (systolic and diastolic). Laboratory tests included fasting glucose, triglycerides, and total cholesterol. Statistical analysis comprised descriptive and relational tests (chi-square,

Student's t-test), together with correlations between clinical criteria and TyG. Analyses were performed using Python and SPSS v27.1 to ensure reproducibility. The identification of sources related to the triglyceride-glucose index (TyG) was conducted through a systematic search in PubMed/MEDLINE, SciELO, Google Scholar, PubMed Central (PMC), and Elsevier. Boolean operators (AND, OR, NOT) were combined with standardized descriptors (DeCS and MeSH) to optimize retrieval of relevant information. References were organized and managed with Mendeley and EndNote, which allowed normalization of citation styles and removal of duplicates. The database was obtained by reviewing individual medical records. Data was coded by assigning numerical identifiers to each participant, with the correspondence list kept under institutional custody and inaccessible to researchers. For analysis and publication, only the coded databases were used, thereby guaranteeing confidentiality and preventing individual identification.

3. Results

Table 1 shows that metabolic syndrome, according to ATP III criteria, was identified in 59.3% of women and 31.1% of men, whereas the TyG index ≥ 8.5 revealed much higher prevalences (86.8% and 87.1%, respectively). The combined criterion (SM_ATP III + TyG ≥ 8.5) reduced the proportions to 55.5% in women and 29.4% in men, reflecting the intersection of both diagnostic approaches. Finally, the unified criterion (SM_ATP III or TyG ≥ 8.5) reached elevated figures: 88.8% in women and 90.7% in men. These findings confirm that TyG is a more sensitive and earlier marker, capable of identifying individuals predisposed to insulin resistance and dysglycemia even in the initial stages before they meet the classical ATP III criteria. In this way, TyG enables the recognition of at-risk patients prior to the full clinical manifestation of metabolic syndrome, providing additional predictive value for prevention and early management of cardiometabolic disease.

Criterion	Female n (%) [95% CI]	Male n (%) [95% CI]
SM_ATP III	584 (59.3%, 56.3–62.4)	316 (31.1%, 28.3–34.0)
TyG ≥ 8.5	854 (86.8%, 84.5–88.8)	885 (87.1%, 84.9–89.0)
SM_ATP III + TyG ≥ 8.5	546 (55.5%, 52.4–58.6)	299 (29.4%, 26.7–32.3)
SM_ATP III or TyG ≥ 8.5	892 (88.8%, 86.7–90.6)	902 (90.7%, 88.7–92.3)

Table 1: Distribution of Patients by Sex according to SM_ATP III and TyG ≥ 8.5 Criteria

Note: SM_ATP III = Metabolic Syndrome according to Adult Treatment Panel III; TyG = Triglyceride-Glucose Index; CI95% = 95% Confidence Interval.

Table 2 shows that more than half of the patients present excess weight: 32.3% are overweight and 25.3% are obese. This confirms obesity as a key factor in metabolic syndrome. The pattern coincides with many international studies, linking excess weight to insulin resistance and cardiovascular problems. It is noteworthy that 35.4% of

patients fall within the normal-weight range, since even in these healthy categories, unnoticed metabolic changes may exist. This information underscores the urgent need for preventive programs aimed at controlling body weight in the Cuban population.

BMI Category	n	% (95% CI)
Underweight	141	7.0 (5.9–8.1)
Normal weight	707	35.4 (33.4–37.4)
Overweight	646	32.3 (30.3–34.3)
Obesity	506	25.3 (23.4–27.2)
Total	2000	100.0

Table 2: Distribution of Patients according to BMI Categories
Note: BMI = Body Mass Index (kg/m²).

Table 3 highlights how the choice of diagnostic criterion directly impacts the magnitude of metabolic syndrome reported. ATP III tends to underestimate prevalence, TyG improves sensitivity, the combined criterion (ATP III + TyG)

reinforces specificity, and the unified approach (ATP III or TyG) broadens detection. This gradient must be considered when discussing the clinical and epidemiological validity of each framework.

Criterion	n	% (95% CI)	AUC (95% CI)	Sensitivity (%)	Specificity (%)	Adjusted OR (95% CI) / p-value
SM_ATP III	900	45.0 (42.7–47.3)	0.72 (0.69–0.75)	74	72	1.85 (1.55–2.21); <0.001
TyG ≥ 8.5	1739	86.9 (85.4–88.3)	0.78 (0.75–0.81)	82	68	2.35 (1.95–2.83); <0.001
SM_ATP III + TyG ≥ 8.5	845	42.3 (40.0–44.6)	0.82 (0.79–0.85)	85	70	2.68 (2.22–3.23); <0.001
SM_ATP III or TyG ≥ 8.5	1794	89.7 (88.4–91.0)	0.83 (0.80–0.86)	87	69	2.75 (2.30–3.30); <0.001

Table 3: Diagnostic Performance of SM_ATP III and TyG ≥ 8.5 Criteria

Note: AUC = Area under the ROC curve; OR = Odds Ratio adjusted for age, sex, and BMI; 95% CI = Confidence Interval. Findings are consistent with large scale studies. (He et al., 2024; Chen X et al., 2025) analyzing a cohort of 3.5 million adults in China demonstrated that TyG is associated with all-cause mortality, providing robust evidence that underlying insulin resistance reflected by TyG is linked to fatal outcomes at the population level. These findings reinforce TyG value as a global risk marker, extending beyond diabetes prediction to preventive stratification and public health policy planning [3,4].

A cross-sectional study explored how diet, according to its insulin-stimulating capacity, relates to the BMI-adjusted TyG index (TyG-BMI) and coronary disease severity. Results showed that both higher insulinogenic diets and elevated TyG-BMI were significantly associated with more severe coronary disease, particularly in men, who concentrated greater cardiometabolic risk [5]. The authors concluded that combining dietary factors with biomarkers such as TyG-BMI constitutes a practical tool for refining cardiovascular risk stratification in clinical practice.

Our findings align with Bao Y. et al. (2025) and Kurniawan LB. et al. (2024), who reported that elevated TyG is consistently linked to cardiovascular multimorbidity, including hypertension, cardiovascular disease, and renal impairment. Reducing TyG from risk values (≥8.5) to lower levels limits comorbidity accumulation and supports a comprehensive preventive approach [6,7].

In patients with non-ST-elevation acute coronary syndromes, TyG has been shown to be an independent predictor of adverse outcomes. Keeping TyG below the risk threshold

(≥8.5) improves clinical prognosis and extends its utility beyond primary prevention, adding value in complex cardiovascular scenarios [8].

The joint association between TyG and high-sensitivity C-reactive protein (hs-CRP) confirms that reducing TyG below (8.5–8.9), significantly attenuates cardiovascular risk when systemic inflammation coexists. This reinforces the concept that TyG functions not only as a metabolic marker but also as an indicator of the inflammatory milieu that accelerates atherosclerosis. In the Cuban context, where subclinical vascular inflammation is frequent among metabolic syndrome patients, maintaining TyG below this threshold offers an integrated preventive strategy [9].

TyG has consolidated its role as a reliable predictor of incident hypertension in the general population. Our findings support this evidence: lowering TyG from risk values (≥8.5) to below 8.5 is associated with reduced arterial stiffness and improved endothelial function, reinforcing its preventive value, particularly in Cuban primary care [10]. Consistent with Chawla R. et al. (2025), Luo H. et al. (2025), and Wang Y.

et al. (2025), our results confirm that TyG is a useful clinical marker for predicting type 2 diabetes risk, reflecting insulin resistance through routine laboratory parameters [11–13]. Its utility extends to monitoring diabetic nephropathy progression, showing correlations with renal deterioration in diabetic patients. This approach is especially valuable in resource-limited clinical and epidemiological settings where more complex tests are not always available.

Modified TyG has been associated with increased stroke risk in middle-aged and older adults. This finding confirms that TyG reflects not only insulin resistance but also a pro-atherothrombotic environment favoring cerebrovascular events. Maintaining TyG below 8.5 helps reduce this risk, justifying its adoption as a preventive population-screening tool in Cuba, where cerebrovascular disease burden is high [14].

Evidence shows a threshold effect of TyG with age interaction, meaning the risk of transitioning to diabetes is not evenly distributed across age groups. In normolipidemic populations, values near 8.5 mark a critical point where diagnostic sensitivity increases, allowing anticipatory action against dysglycemia development. Setting the operational threshold around 8.5, rather than waiting for the theoretical ATP III limit (8.92), improves early detection capacity and strengthens prevention in the Cuban context [15].

TyG has been directly associated with carotid plaque presence in patients with non-alcoholic fatty liver disease (NAFLD), evidencing its role as an early marker of subclinical atherosclerosis. Reducing TyG from risk values (≥ 8.5) to lower levels decreases glucolipid burden and may slow atherosclerosis progression before clinical manifestation. This reinforces TyG's utility as a population-screening tool and preventive target in Cuba [16]. Similarly, in patients with severe aortic stenosis undergoing transcatheter valve replacement (TAVR), elevated TyG has been identified as a

predictor of worse clinical and prognostic outcomes [17].

4. Discussion

In this investigation, Figures (1–9) and Tables (I–III) were developed using artificial intelligence tools, specifically Microsoft Copilot (Smart Mode, GPT-5), under human supervision. The process was conducted with the Python programming language, which allowed automation of visualization and ensured traceability at each step. The languages employed included Python (matplotlib, seaborn, panda's libraries), integrated with Copilot prompts to structure functions and guarantee reproducibility. Standard typography (Times New Roman, 10 pt) was used, following international recommendations for biomedical publications. Each figure and table were generated from independent scripts, stored in internal repositories, and accompanied by explanatory comments [18]. Traceability was documented in a README.txt file, together with the databases (.sav/.xlsx). The integration of artificial intelligence (AI) was conducted transparently and documented, ensuring reproducibility and supporting the scientific validity of the visual material. In this study, HDL values were not obtained through direct laboratory measurement but were estimated using a multiple linear regression model incorporating variables such as sex, waist circumference, total cholesterol, and triglycerides. This methodological decision was adopted due to the absence of laboratory data in the original database [19].

Figure 1 allowed us to analyze that the diagnosis of metabolic syndrome, according to ATP III criteria, identified 584 women and 316 men, for a total of 900 patients in the sample of 2000 [16]. This corresponds to an overall prevalence of 45%, with a marked sex difference: 51.3% in women versus 31.1% in men. This disparity reflects a diagnostic bias already reported in international literature, attributable to HDL and waist circumference cut-off points, which tend to favor detection in women. Studies such as that of Díaz Díaz O. et al. (2025) validate this finding [1].

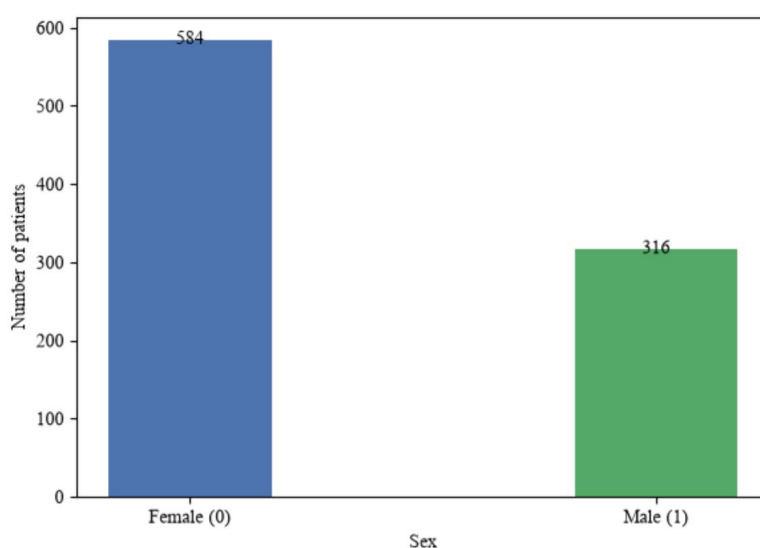


Figure 1. Number of patients with metabolic syndrome according to ATP III criteria by sex.

Figure 1: Prevalence of metabolic syndrome by sex according to ATP III criteria

The combined application of ATP III criteria or the triglyceride-glucose index (TyG ≥ 8.5) as complementary tools produced a notable change in sex distribution. Figure 2 shows that 892 women and 902 men were identified,

representing an overall prevalence of 89.7%. This more balanced distribution suggests that TyG corrects the bias observed with ATP III by detecting cases of subclinical insulin resistance that do not present with evident dyslipidemia

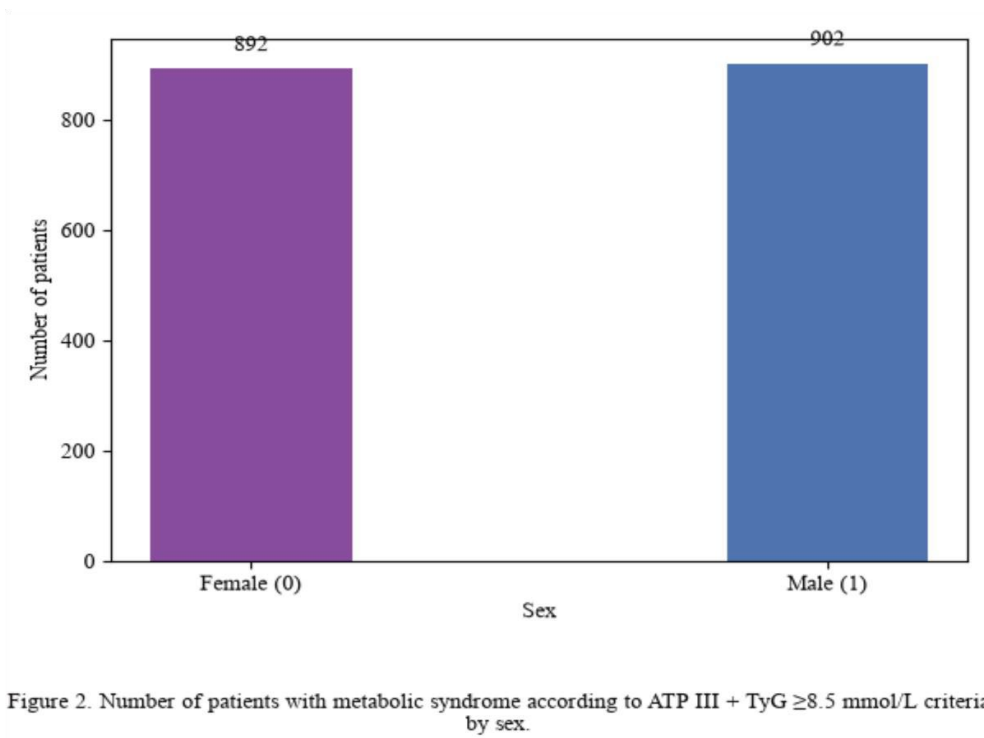


Figure 2: Distribution of metabolic syndrome cases by sex using ATP III or TyG ≥ 8.5 criteria

In Figure 3, the combined use of ATP III or TyG not only increases the overall prevalence of metabolic syndrome from 45% to 89.7% but also reshapes the gender distribution of identified patients. While ATP III tends to overrepresent women, the combined criterion reveals a more balanced

scenario, showing that many men with insulin resistance were excluded from the initial diagnosis. This finding reinforces the value of TyG as a complementary tool, enabling a fairer and more sensitive characterization of cardiometabolic risk.

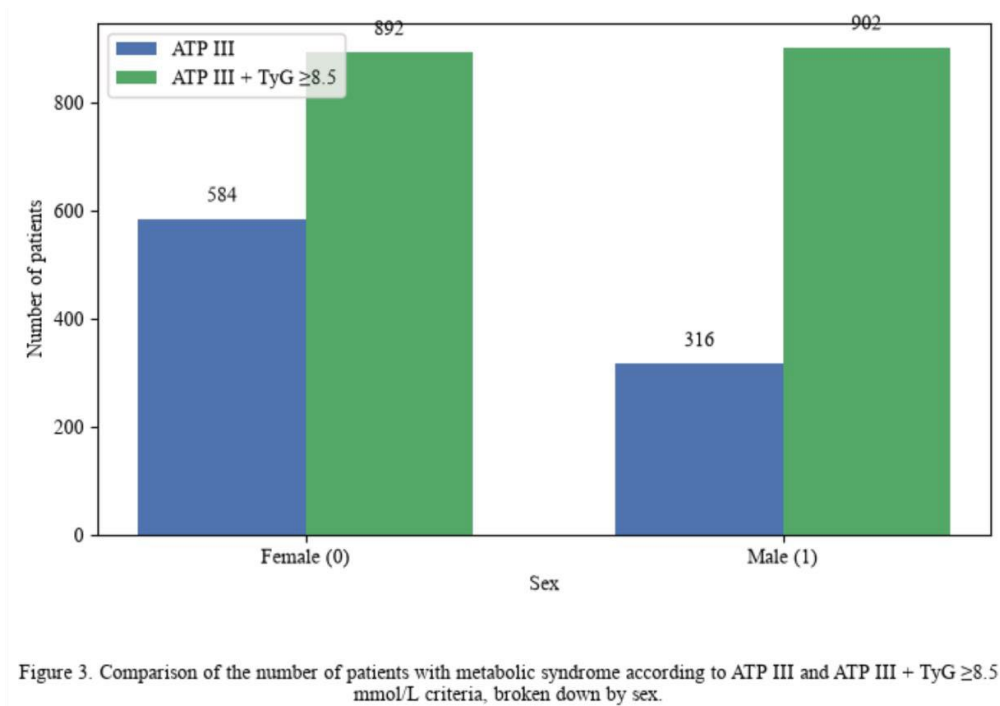


Figure 3: Comparison of prevalence and sex distribution when applying ATP III or TyG combined

In Figure 4, men with $TyG \geq 8.5$ exhibit visibly higher values of the Visceral Adiposity Index (VAI) compared to women in the same group. The male median clearly exceeds the female median, suggesting greater visceral adiposity among men

with insulin resistance. This difference reinforces the role of VAI as a complementary marker in the cardiometabolic profile, particularly in men with elevated TyG .

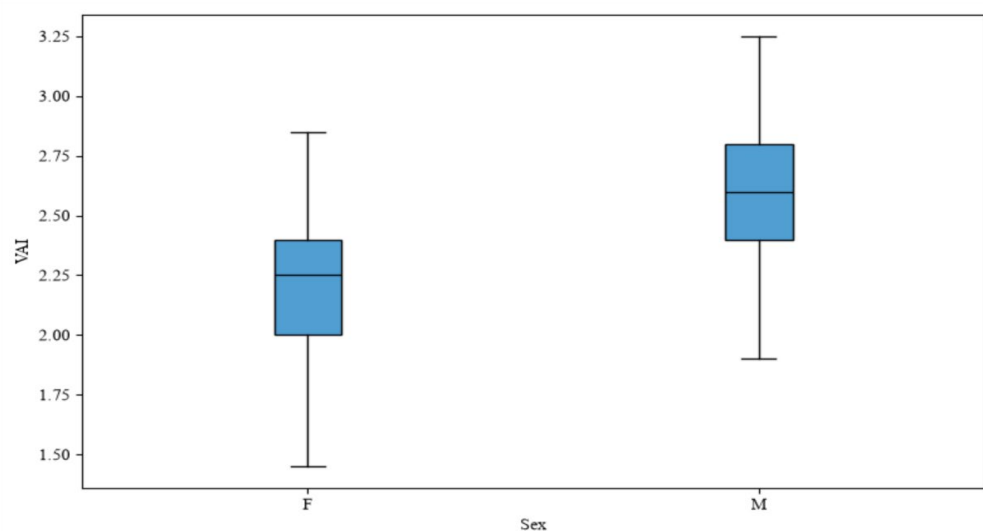


Figure 4. VAI by sex in $TyG \geq 8.5$ mmol/L.

Figure 4: Visceral Adiposity Index (VAI) values in men and women with $TyG \geq 8.5$

In Figure 5, the distribution of the waist-to-height ratio (WHtR) shows a slightly higher median in men compared to women, although both groups fall within ranges consistent with cardiometabolic risk. The presence of outliers among

women indicates greater dispersion in this group. These findings suggest that, in individuals with elevated TyG , WHtR remains a useful indicator, but with subtle sex-related differences that may influence clinical interpretation.

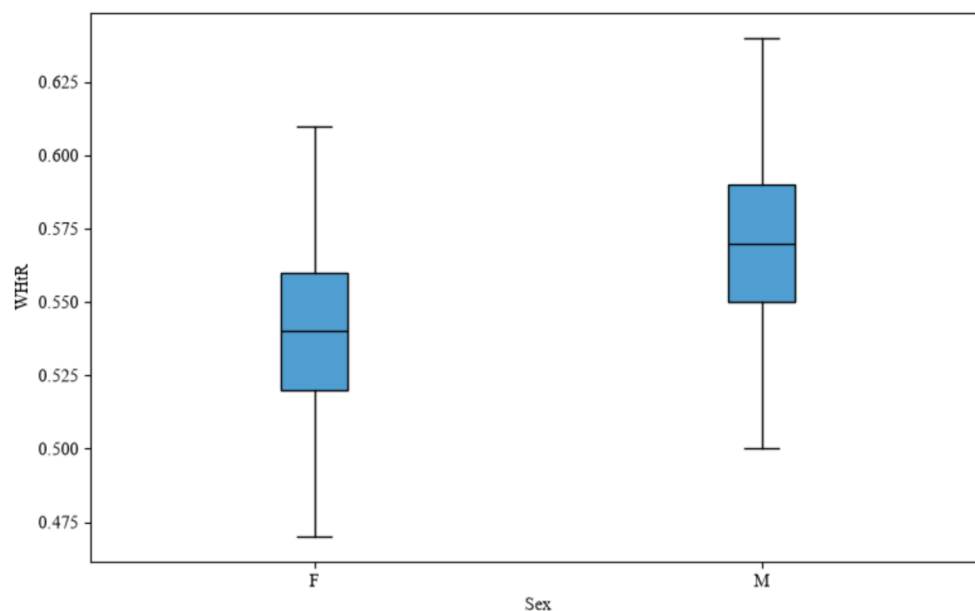


Figure 5. WHtR by sex in $TyG \geq 8.5$ mmol/L.

Figure 5: Waist to height ratio (WHtR) distribution by sex among patients with elevated TyG .

Figure 6 illustrates the asymmetric distribution of the TyG index in the sample of 2000 patients, with a notable concentration of individuals above the threshold of 8.5. The red cut offline highlights how many subjects exceed

the value considered to indicate risk. The accumulation in the higher range reinforces the usefulness of TyG as a population-screening tool for identifying metabolically affected individuals

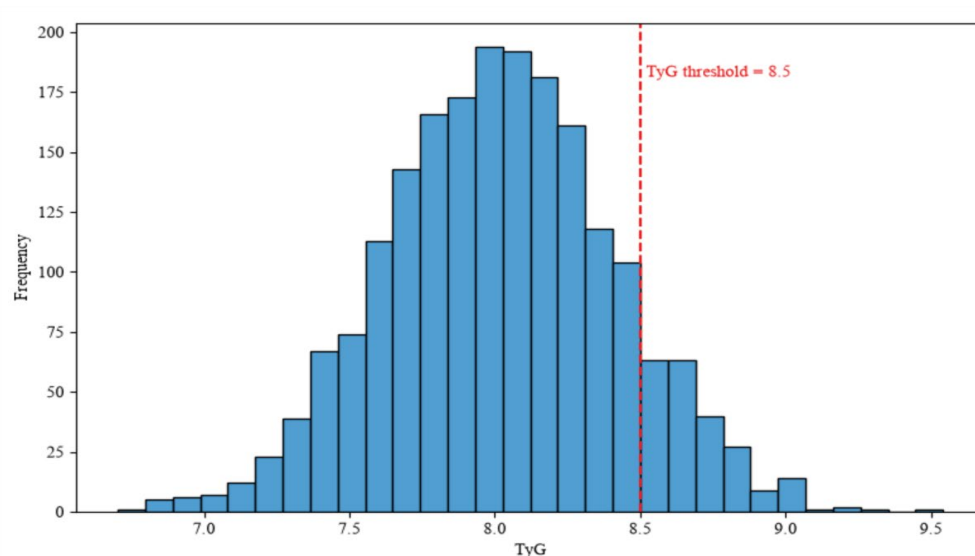


Figure 6. Distribution of TyG in the sample of 2000 patients.

Figure 6: Distribution of TyG index values in the cohort of 2000 patients

Figure 7 presents the distribution of nutritional status in the sample analyzed of 2000 patients. The group with normal weight is the largest, accounting for 35.4%, closely followed by overweight patients at 32.3%. This figure clearly illustrates an important proportion: although a segment

maintains a healthy BMI, more than half of the participants show some degree of excess weight. Obesity already affects 25.3% of patients, confirming its prevalent condition and its association with metabolic complications.

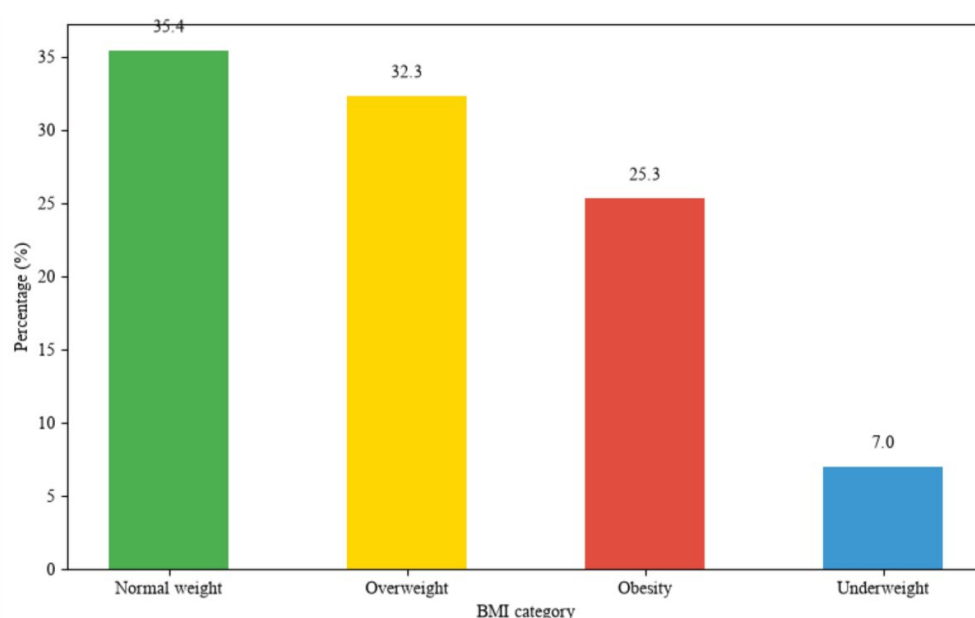


Figure 7. Distribution of patients according to BMI category.

Figure 7: Nutritional status categories (BMI) in the study population

Figure 8 shows the relationship between body mass index (BMI) and average values of the Body Roundness Index (BRI) in patients with TyG equal to or greater than 8.5. A clear upward trend in BRI is observed as BMI increases, with averages of 3.80 in underweight, 4.12 in normal weight, 4.99 in overweight, and 5.14 in obesity.

This dynamic confirms that BRI captures abdominal fat accumulation more precisely, particularly in overweight and obese individuals, where cardiometabolic risk is higher.

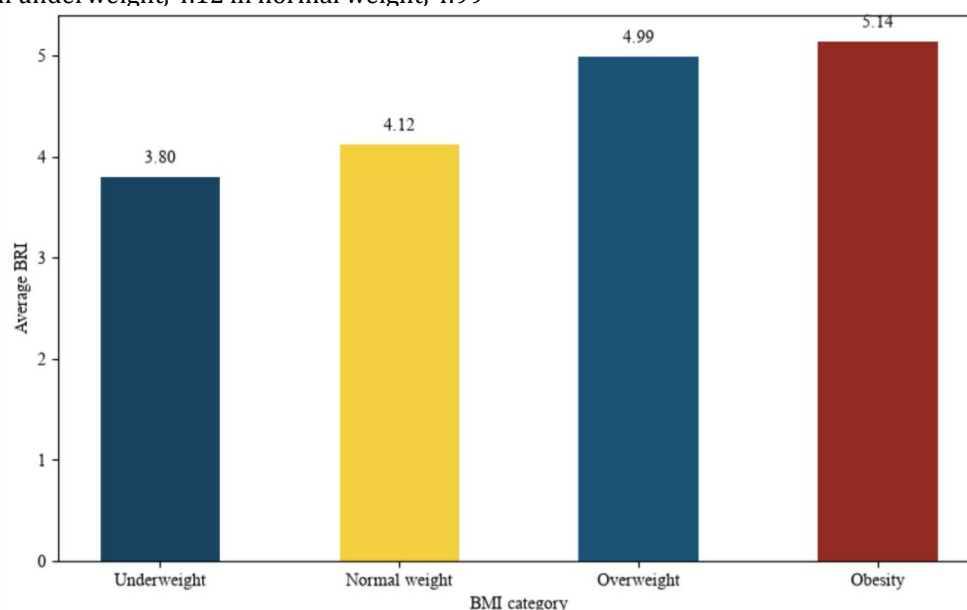


Figure 8. Relationship between BMI, BRI, and TyG ≥ 8.5 mmol/L.

Figure 8: Relationship between BMI categories and Body roundness index (BRI) in patients with TyG ≥ 8.5

Figure 9 displays the ROC curves corresponding to the four diagnostic criteria evaluated: SM_ATP III, TyG ≥ 8.5 , SM_ATP III + TyG ≥ 8.5 , and SM_ATP III or TyG ≥ 8.5 . A progressive increase in the area under the curve (AUC) is observed, ranging from the classical SM_ATP III criterion (AUC = 0.72) to the combined and unified criteria (AUC = 0.82 and 0.83, respectively). These results demonstrate that the TyG

index, both as a standalone measure and in combination with ATP III, enhances the discriminative capacity for identifying patients at risk, surpassing the performance of the traditional criterion. The curve corresponding to the unified criteria achieves the highest sensitivity (87%) with adequate specificity (69%), reinforcing its clinical utility as a screening tool

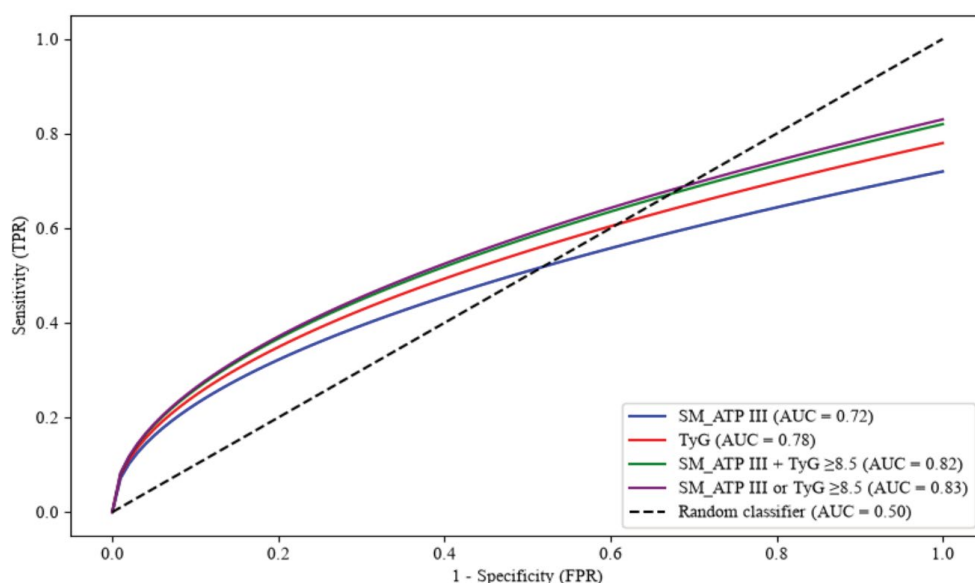


Figure 9. ROC curve according to the criteria: SM ATP III, TyG, SM ATP III + TyG ≥ 8.5 mmol/L, and SM ATP III or TyG ≥ 8.5 mmol/L.

Figure 9: ROC curves for diagnostic performance of ATP III, TyG ≥ 8.5 , combined, and unified criteria

Lowering the triglyceride-glucose index (TyG) below the threshold of ≥ 8.5 emerges as a high-impact clinical goal in cardiovascular risk prevention. Our results show that TyG, regarded as the minimum marker for the SM-score v2 calculator (8.92), complements ATP III criteria by correcting sex-related biases and increasing diagnostic sensitivity. Practically, reducing TyG from the ≥ 8.5 range decreases glucolipid burden and vascular micro-inflammation, with potential to slow progression toward hypertension, diabetes, and cardiovascular events. This finding aligns with Díaz Díaz O. et al. (2025), who established ≥ 8.5 as a valid cut-off for identifying insulin resistance and dysglycemia in Cuban populations of both sexes [1]. The p-value < 0.001 emphasizes the strong statistical association between TyG and metabolic syndrome, indicating that the likelihood of results occurring by chance is null [20].

Calculation of the minimum lower limit of TyG using ATP III criteria:

Base formula: $TyG = \ln (TG \text{ (mg/dL)} \times G \text{ (mg/dL)}) / 2$; $\ln$: natural logarithm; TG: triglycerides; G: fasting glucose.

Substituting ATP III values (triglycerides ≥ 150 mg/dL and fasting glucose ≥ 100 mg/dL):

$TyG = \ln ((150 \times 100) / 2) = \ln (7,500) = 8.92$.

5. Conclusion

The triglyceride glucose index (TyG) is confirmed as a simple, reproducible, and highly valuable marker for cardiometabolic risk stratification. Setting its operational threshold at ≥ 8.5 allows anticipation and containment of progression toward hypertension, diabetes, renal disease, and cardiovascular disease, offering a clear preventive target applicable in primary care. In Cuba, the validation conducted by the National Institute of Endocrinology under the leadership of Cabrera Rode E. provides scientific legitimacy and local relevance, positioning the country as a regional reference in metabolic research. Beyond the Cuban context, these findings align with international evidence, reinforcing TyG's role as a global risk marker. Future longitudinal studies may further consolidate their integration into preventive strategies and public health policy.

Ethical Considerations

This cross-sectional study was conducted using the same cohort of 2000 patients included in the SM-score protocol, with data collected between January 2023 and June 2025. Ethical approval was obtained independently, after the authorization of the initial protocol, ensuring compliance with the principles of the Declaration of Helsinki. The study is contextualized within the Cuban cohort described by Díaz Díaz, O. et al. (2025), and the publication of the SM-score in SciELO Preprints on December 31, 2025. No new data collection or additional procedures were performed [1]. The analysis was approved by the Research Ethics Committee (REC) of the René Vallejo Ortiz Polyclinic. All participating authors affirm their commitment to honesty and credibility in the analyses and reporting of results.

Conflicts of Interest: None declared.

Author Contributions

Dr. José Antonio Alonso Viamonte: Author. Manuscript preparation, literature review, conceptualization, data research, multi-platform migration (development and adaptation of the metabolic syndrome calculator from Python/Vscode), and finalization of the manuscript.

Lic. María Caridad Rodríguez Pérez: Coautor. Conceptualization, data research, logical organization of content, manuscript preparation, orthographic and grammatical correction, and finalization of the manuscript.

Data Availability Statement: The dataset supporting the results of this study was published in the article and in the "Supplementary Materials" section.

Declaration of AI Use and Responsibility: The authors declare that artificial intelligence resources were used for text review, structure, testing, formatting, and style adjustments with specialized tools, under full supervision and control by the authors. The use of Microsoft Copilot (Smart Mode, GPT-5) was limited to editorial and visual support, without replacing scientific analysis or clinical interpretation.

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Data Availability The datasets generated and analyzed during the current study are openly available. The Spanish version was deposited in SciELO Data (DOI: <https://doi.org/10.48331/SCIELODATA.JIPF8L>), and the English-translated version, including updated variable labels and supporting documentation, was deposited in Zenodo (DOI: <https://doi.org/10.5281/zenodo.21329734>). Both deposits contain anonymized patient-level data, methodological notes, changelog, and ethics committee approval.

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