Nutrition 109 (2023) 111978

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Applied nutritional investigation

Accuracy of the triglyceride-glucose index as a surrogate marker for identifying metabolic syndrome in non-diabetic individuals

Analie Nunes Couto Ph.D. [a,*], Hildegard Hedwig Pohl Ph.D. [b], Moisés Evandro Bauer Ph.D. [a,d,e], Carla Helena Augustin Schwanke M.D., Ph.D. [a,c]

[a] Graduate Program in Biomedical Gerontology, School of Medicine, Pontifical Catholic University of Rio Grande do Sul (PUCRS), Porto Alegre, Brazil
[b] Graduate Program in Health Promotion, University of Santa Cruz do Sul, Santa Cruz do Sul, Brazil
[c] Institute of Geriatrics and Gerontology, Pontifical Catholic University of Rio Grande do Sul (PUCRS), Porto Alegre, Brazil
[d] Laboratory of Immunobiology, School of Health and Life Sciences, Pontifical Catholic University of Rio Grande do Sul (PUCRS), Porto Alegre, Brazil
[e] National Institute of Science and Technology – Neuroimmunomodulation (INCT-NIM), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brasília, Brazil

ARTICLE INFO

Article History:
Received 16 October 2021
Received in revised form 14 January 2023
Accepted 15 January 2023

Keywords:
Metabolic syndrome
Insulin resistance
Triglyceride-glucose index
Health
Rural
Rural population
Farmers

ABSTRACT

Objectives: This study aimed to verify the performance of the triglyceride-glucose (TyG) index in predicting metabolic syndrome (MetS) using three different criteria in healthy individuals living in rural areas. In addition, it aimed to estimate the TyG index cutoff point in the prediction of MetS.
Methods: The study was a cross-sectional study of healthy individuals (aged ≥18 y) living in rural areas of southern Brazil. Individuals with diabetes mellitus were excluded. The variables investigated were waist circumference, blood pressure, triglycerides, high-density lipoprotein cholesterol, fasting glucose, and TyG index. MetS was defined using three criteria: harmonized, International Diabetes Foundation, and National Cholesterol Education Program Adult Treatment Panel III. The Poisson regression model was used for the multivariate analysis. The performance of the TyG index in identifying MetS was determined by receiver operating characteristic curves.
Results: A total of 133 individuals were included in this study, with a mean age of 49.0 ± 13.5 y; 54.1% were female. The TyG index performed better in predicting MetS through the harmonized criteria, with area under the curve (AUC) = 0.889 (95% confidence interval [CI], 0.829–0.949), followed by the International Diabetes Foundation criteria, with AUC = 0.877 (95% CI, 0.814–0.940), and the National Cholesterol Education Program criteria, with AUC = 0.867 (95% CI, 0.797–0.937). The TyG index cutoff points defined for the harmonized and International Diabetes Foundation criteria were ≥ 8.61, and ≥ 8.79 for the National Cholesterol Education Program Adult Treatment Panel III.
Conclusions: The TyG index proved to be valid for diagnosing MetS. The largest AUC of the TyG index was identified for the harmonized criteria. Thus, the TyG index can be used to diagnose MetS in individuals living in rural areas.

Introduction

Metabolic syndrome (MetS) is defined by a set of related physiological, biochemical, clinical, and metabolic factors that increase the risk for cardiovascular disease, diabetes mellitus, and other causes of mortality [1,2]. The prevalence of MetS varies according to sex, age, race and ethnicity, and geographic region as well as the influence of the urban or rural environment. The worldwide prevalence is estimated to range from <10% to 84% [3]. In Brazil, the prevalence of MetS in adults was estimated at 33% [4].

Aging is the major contributing factor for the metabolism decline and a strong risk factor for high blood pressure, cardiovascular disease, stroke, cancer, and diabetes. The components of risk factors that define MetS include central obesity, hyperglycemia, hypertension, low levels of high-density lipoprotein cholesterol (HDL-C), and circulating hypertriglyceridemia [5–7].

Insulin resistance is the main cause of MetS. The hyperinsulinemic-euglycemic clamp is the gold standard technique for assessing insulin sensitivity in humans. However, it requires sophisticated and invasive methods that are not available for use in daily clinical practice. Considering these difficulties, other useful markers to

This article was supported by grants from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES – Finance Code 001).
*Corresponding Author: Tel: 55 51 998744466
E-mail address: analiecouto@hotmail.com (A.N. Couto).

https://doi.org/10.1016/j.nut.2023.111978
0899-9007/

assess insulin resistance have been proposed, such as the assessment of the homeostatic model of insulin resistance, which is low cost, simple, and requires only the measurement of blood glucose and insulinemia after fasting for 8 to 12 h [8,9].

Simental-Mendía et al. [10] developed and validated an index obtained through the product of fasting glucose and plasma triglycerides (TyG index). The same authors found that TyG can be used as a surrogate marker to identify insulin resistance, with good sensitivity and specificity in apparently healthy individuals. Du et al. [11] directly compared the TyG index with other lipid and apolipoprotein measures—lipid ratios and lipid indices (visceral adiposity index and lipid accumulation product)—to measure the efficiency in detecting insulin resistance; the TyG index proved the most efficient marker for early identification of insulin resistance. TyG is a simple index, reflecting insulin resistance and has also been a good predictor for screening MetS [12–14].

The TyG index has been validated across different populations, many of them from urban areas [13,15,16]. However, populations living in rural areas, compared with urban areas, have a greater number of health-related issues, seek less medical assistance, and undergo fewer routine examinations—mainly due to transport limitations, distance from social and health resources, low income, and chronic health problems [17–19].There are few data evaluating MetS in individuals from rural areas [20,21]. As far as we know, the use of the TyG index to diagnose MetS in Brazilian rural areas, without a diagnosis of diabetes, has not been studied. The identification of a low-cost alternative index, which presents simplicity, speed, and functionality to diagnose effectively, is essential for the screening of metabolic disorders, especially those assisted in primary health care [22].

Therefore, the objectives of the present study are 1) to verify the performance of the TyG index to predict MetS by using different criteria in individuals without diabetes mellitus and living in rural areas and 2) to estimate the TyG index cut-off point in predicting MetS.

Methods

Study design and subjects

This is a cross-sectional study performed with data from the database, Screening of Risk Factors Related to Overweight in Agribusiness Workers Using New Analytical and Health Information Technologies – PHASE III, from the University of Santa Cruz do Sul, Brazil. A total of 141 individuals, aged >18 y, were recruited using convenience sampling, living in rural areas of five cities in the countryside of the state of Rio Grande do Sul, Brazil (Encruzilhada do Sul, Rio Pardo, Candelária, Passo do Sobrado, and Vale Verde). All participants were owners of small agribusinesses or rural properties workers. Only individuals who presented complete data for the diagnosis of MetS and the determination of the TyG index were included. Individuals with a previous diagnosis of diabetes mellitus or using medication to treat this condition were excluded. Data were collected between April 2018 and November 2019.

This study was part of the project, Screening of Risk Factors Related to Overweight in Agribusiness Workers Using New Analytical and Health Information Technologies – PHASE III, and approved by the Institutional Review Boards of the University of Santa Cruz do Sul and Pontifical Catholic University of Rio Grande do Sul (CAAE: 78889317.1.0000.5343). All participants were fully informed about the procedures and possible risks involved before providing written and informed consent.

The sample size was estimated with the WinPEPI (Programs for Epidemiologists for Windows) version 11.43 and based on the studies by Shin and Kim [12], Unger et al. [15], and Li et al. [16], with an estimated prevalence of MetS in 25%. The standardized effect size was estimated to detect differences in the TyG index between individuals with and without MetS. In previous reference studies, effect sizes were reported from 0.8 to 1.5 SDs. Thus, the minimum value for the effects found was used (0.8). Considering a significance level of $P = 0.05$, a power of 90%, and a sample ratio of 1:3; 64 subjects (16 cases and 48 controls) should be recruited.

Sociodemographic, anthropometric, and lifestyle assessments

Sociodemographic and lifestyle variables were collected with a general questionnaire, including sex, age, education, marital status, smoking, and alcohol consumption. Weight (in kilograms) was measured using a Welmy anthropometric scale (Santa Bárbara d'Oeste, Brazil), with the individuals barefoot and wearing light clothing. Height (in meters) was measured using a stadiometer attached to the scale, with the individuals barefoot; standing with their backs, buttocks, and backs of their knees against the stadiometer; heels together and toes apart; and observing the Frankfurt plane. Waist circumference (minimum size between the lowest rib and the iliac crest) was determined with a flexible and inelastic measuring tape made by Cardiomed (Curitiba, Brazil).

The body mass index was classified as underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2), or obese (≥30 kg/m^2) [23].

Blood pressure was preferably measured in the right arm by the indirect method with the auscultatory technique and using an aneroid sphygmomanometer (Tycos, North Carolina), properly calibrated and appropriate cuff for obese patients. The individuals were seated, at rest for at least 5 min, with an empty bladder. Two measurements were taken using the mean value (mm Hg).

Biochemical assessments

Venous blood samples were drawn after a 12-h overnight fast. Samples were processed and analyzed on the same day at the Exercise Biochemistry Laboratory of the University of Santa Cruz do Sul. Serum levels of HDL-C, triglycerides, and glucose were measured by automated equipment (Miura 200; I.S.E., Rome, Italy) with commercially available kits (DiaSys Diagnostic Systems Holzheim, Germany).

The TyG index was calculated according to the natural logarithm ln (fasting triglycerides [mg/dL] × fasting glucose [mg/dL]/2), expressed as a logarithmic scale [9].

Diagnosis of the metabolic syndrome

MetS was established according to different diagnostic criteria: 1) harmonized criteria of the American Heart Association/National Heart, Lung, and Blood Institute (AHA/NHLBI) and International Diabetes Federation (IDF); 2) IDF [24]; and 3) revised criteria of the National Cholesterol Education Program Adult Treatment Panel III (NCEP/ATPIII) [25].

Statistical analysis

All analyses were performed using the SPSS version 21.0 (IBM Corp., Armonk, NY, USA). All variables were tested for normal distribution using the Kolmogorov-Smirnov test. Continuous variables were described as mean and SD. Categorical variables were presented in absolute and relative numbers. Regarding MetS, three diagnostic criteria were performed (harmonized, IDF, and NCEP/ATPIII) in all analyses. The Student's t test was used to

compare the means of the TyG index and MetS. The Poisson regression model was used as a multivariate analysis, adjusted for sex, age, and education (confounding variables associated with the outcome in the uni- and bivariate analyses), in which the following receiver operating characteristic variables were included: MetS (outcome) and TyG index (predictor variable). The receiver operating characteristic curve was performed to assess the predictive ability of the TyG index (the test variable) for MetS (the state variable). An area under the curve (AUC) > 0.7 was considered adequate for predicting with acceptable accuracy [26]. The cutoff points of the TyG index for the three MetS criteria were established from the Youden index [27]. Sensitivity, specificity, positive predictive value, and negative predictive value were calculated for all MetS criteria.

Statistical significance was accepted as $P < 0.05$. This study was conducted according to the Standards for Reporting of Diagnostic Accuracy guidelines [28].

Results

The final sample consisted of 133 participants (mean age = 49.0 ± 13.5 y, ranging from 18 to 83 y), because eight individuals were diagnosed with diabetes mellitus.

The sociodemographic, lifestyle, clinical, and MetS characteristics of the sample are described in Table 1. Most of the sample was composed of adult women who did not have MetS. Most individuals were married or living with a partner and had low education (lower

Table 1
Sociodemographic, clinical, and lifestyle characteristics of non-diabetic individuals from rural areas (n = 133)

		MetS harmonized		MetS IDF		MetS NCEP/ATPIII	
Variables	Total sample *n* (%)	No *n* (%)	Yes *n* (%)	No *n* (%)	Yes *n* (%)	No *n* (%)	Yes *n* (%)
Sex							
Female	72 (54.1)	48 (50.0)	24 (64.9)	48 (49.5)	24 (66.7)	53 (52.0)	19 (61.3)
Male	61 (45.9)	48 (50.0)	13 (35.1)	49 (50.5)	12 (33.3)	49 (48.0)	12 (38.7)
Age group							
Adults (18–59 y)	102 (76.7)	73 (76.0)	29 (78.4)	74 (76.3)	28 (77.8)	78 (76.5)	24 (77.4)
Older adults (≥60 y)	31 (23.3)	23 (24.0)	8 (21.6)	23 (23.7)	8 (22.2)	24 (23.5)	7 (22.6)
Marital status							
Without a partner	31 (23.3)	23 (24.0)	8 (21.6)	23 (23.7)	8 (22.2)	24 (23.5)	7 (22.6)
Married or living with partner	102 (76.7)	73 (76.0)	29 (78.4)	74 (76.3)	28 (77.8)	78 (76.5)	24 (77.4)
Education							
≤4 y	62 (46.6)	38 (39.6)	24 (64.9)	39 (40.2)	23 (63.9)	41 (40.2)	21 (67.7)
5–8 y	42 (31.6)	34 (35.4)	8 (21.6)	34 (35.1)	8 (22.2)	37 (36.3)	5 (16.1)
>8 y	29 (21.8)	24 (25.0)	5 (13.5)	24 (24.7)	5 (13.9)	24 (23.5)	5 (16.1)
Smoking status							
Never smoked	96 (72.2)	73 (76.0)	23 (62.2)	73 (75.3)	23 (63.9)	78 (76.5)	18 (58.1)
Previous smoker	29 (21.8)	17 (17.7)	12 (32.4)	18 (18.6)	4 (11.1)	18 (17.6)	11 (35.5)
Current smoker	8 (6.0)	6 (6.3)	2 (5.4)	6 (6.2)	2 (5.6)	6 (5.9)	2 (6.5)
Alcohol consumption							
Not using	67 (50.8)	44 (65.7)	23 (62.2)	44 (45.4)	23 (63.9)	49 (48.0)	18 (58.1)
Monthly	32 (24.2)	28 (29.5)	4 (10.8)	28 (28.9)	4 (11.1)	28 (27.5)	4 (12.9)
Weekly	33 (25.0)	23 (24.2)	10 (27.0)	24 (24.7)	9 (25.0)	24 (23.5)	9 (29.0)
BMI[*]							
Normal weight	40 (30.1)	39 (40.6)	1 (2.7)	40 (41.2)	0	39 (38.2)	1 (3.2)
Overweight	53 (39.8)	38 (39.6)	15 (40.5)	28 (39.2)	15 (41.7)	43 (42,2)	10 (32.2)
Obesity	40 (30.1)	19 (19.8)	21 (56.8)	19 (19.6)	21 (58.3)	20 (19.6)	20 (64.5)
Elevated waist circumference[†]							
No	46 (34.6)[‡]	45 (46.9)	1 (2.7)	46 (47.4)	0	79 (77.5)	10 (32.3)
Yes	87 (65.4)[‡]	51 (53.1)	36 (97.3)	51 (52.6)	36 (100)	23 (22.5)	21 (67.7)
Systemic blood pressure[§]							
Normal	71 (53.4)	67 (69.8)	4 (10.8)	67 (69.1)	4 (11.1)	69 (67.6)	2 (6.5)
Elevated	62 (46.6)	29 (30.2)	33 (89.2)	30 (30.9)	32 (88.9)	33 (32.4)	29 (93.5)
Fasting glucose levels[‖]							
Normal	104 (78.2)	82 (85.4)	22 (59.5)	83 (85.6)	21 (58.3)	86 (84.3)	18 (58.1)
Elevated	29 (21.8)	14 (14.6)	15 (40.5)	14 (14.4)	15 (41.7)	16 (15.7)	13 (41.9)
HDL-C[¶]							
Normal	121 (91.0)	91 (94.8)	30 (81.1)	92 (94.8)	29 (80.6)	96 (94.1)	25 (80.6)
Reduced	12 (9.0)	5 (5.2)	7 (18.9)	5 (5.2)	7 (19.4)	6 (5.9)	6 (19.4)
Triglycerides[#]							
Normal	101 (75.9)	90 (93.8)	11 (29.7)	90 (92.8)	11 (30.6)	92 (90.2)	9 (29.0)
Elevated	32 (24.1)	6 (6.3)	26 (70.3)	7 (7.2)	25 (69.4)	10 (9.8)	22 (71.0)
Total sample	133	96 (72.2)	37 (27.8)	97 (72.9)	36 (27.1)	102 (76.7)	31 (23.3)

BMI, body mass index; harmonized, criteria of the American Heart Association/National Heart, Lung, and Blood Institute and IDF; HDL-C, high-density lipoprotein cholesterol; IDF, International Diabetes Federation; MetS, metabolic syndrome; NCEP/ATPIII, revised criteria of the National Cholesterol Education Program Adult Treatment Panel III
[*]Eutrophy: 18.5–24.9 kg/m^2; overweight: 25–29.9 kg/m^2; and obesity: ≥30 kg/m^2.
[†]Defined according to each of the MetS criteria.
[‡]Defined according to harmonized criteria of American Heart Association/National Heart, Lung, and Blood Institute and IDF (≥90 cm for men; ≥80 cm for women)
[§]Treatment or ≥130/85 mm Hg.
[‖]≥100 mg/dL.
[¶]Treatment or ≥150 mg/dL.
[#]For women, <40 mg/dL; for men, <50 or treatment.

education ≤4 y). Most participants were non-smokers and did not consume alcoholic beverages. Subjects were most often overweight, obese, and centrally obese. Most of them had normal systemic blood pressure, blood glucose, HDL-C, and triglyceride levels.

Among those who presented with MetS, most were women, ages between 18 and 59 y, and married or living with a partner and had low education. Most were also non-smokers and did not consume alcoholic beverages. Individuals with MetS were more often obese and had elevated waist circumference, systemic blood pressure, and triglycerides.

No age group associations were identified (18–59 versus ≥60 y) with MetS frequency and the TyG index (continuous variable) (P = 0.775 and P = 0.128, respectively). Then, subsequent analyses were performed on the total sample.

Among the five components of MetS diagnosis, only HDL-C was not associated with TyG index (Supplemental Table 1).

The TyG index mean in the total sample was 8.66 ± 0.42 and, according to each of the diagnostic criteria, the index was higher among participants with MetS (P <0.001). In the multivariate analysis, individuals with a high TyG index had an increased occurrence of MetS diagnosed by the three criteria. However, the MetS prevalence ratio by the harmonized criteria had less variability, with a prevalence ratio of 500.9% (95% confidence interval [CI], 289.90–826.1), thus explaining that the TyG index was associated with the occurrence of MetS (Table 2). The TyG index was associated with MetS even without considering the fasting glucose and triglyceride components (Supplemental Table 2).

The performance of the TyG index in predicting MetS, according to each of the diagnostic criteria, is illustrated in Figure 1. The largest AUC was identified when using the harmonized criteria.

The TyG index cutoffs for the three MetS criteria, established from the Youden index— sensitivity, specificity, positive predictive value, and negative predictive value for each of the MetS criteria—are listed in Table 3. The optimal cutoff values for the MetS prediction for the harmonized, IDF, and NCEP/ATPIII MetS criteria were 8.61, 8.61, and 8.79, respectively.

Discussion

The performance of the TyG index in predicting MetS according to different criteria (harmonized, IDF, and NCEP/ATPIII) in individuals living in rural areas without a diagnosis of diabetes mellitus was evaluated. The TyG index presented the largest AUC by the harmonized criteria for MetS prediction, with a cutoff point established at 8.61, with excellent sensitivity and negative predictive value.

The results also indicated that TyG index can be a useful tool for identifying MetS. The use of simple, inexpensive, and effective screening methods is important in clinical practice in primary health care [22], because early identification and immediate management of MetS are vital for preventing cardiovascular diseases and diabetes [2].

The TyG index was considered a surrogate marker of insulin resistance in apparently healthy individuals compared with the homeostatic model of insulin resistance index, with good sensitivity (84.0%) and specificity (45.0%) and with positive and negative predictive values of 81.1% and 84.8%, respectively [10]. In 2010, the same group of researchers evaluated the sensitivity and specificity of the TyG index in identifying insulin resistance with the hyperinsulinemic-euglycemic clamp test and had 96.5% sensitivity and 85.0% specificity (AUC = 0.858), suggesting that it is a useful tool in identifying the decrease in insulin sensitivity [29].

A previous study in Brazil has investigated the performance of the TyG index in adults and older adults in identifying insulin resistance, finding that it is significantly correlated with the hyperglycemic clamp (TyG index: AUC = 0.79 [95% CI, 0.69–0.89]) and considered a useful tool and accessible for the assessment of insulin resistance in the Brazilian population [30]. The TyG index is referred to as one of the main markers to estimate the sensitivity to insulin resistance in clinical practice by the Guidelines of the Brazilian Society of Diabetes [31]. However, it does not provide an indication of cutoff points for the Brazilian population.

The TyG index had the largest AUC for predicting MetS using the harmonized criteria in our study, with sensitivity of 0.946, specificity of 0.667, and positive and negative predictive values of 0.522 and 0.970 (AUC = 0.889 [95% CI, 0.829–0.949]). The AUC TyG index predicting MetS was higher than in a study of adults in Nigeria with AUC = 0.796 (95% CI, 0.757–0.831) [13]. The AUC TyG index reported in this study was also higher than that found in a national survey conducted in China [32], 0.863 (95% CI, 0.857–0.869) and 0.867 (95% CI, 0.862–0.872) for men and women. In addition, the AUC TyG reported here was higher than the study by Endukuru et al. [33], with AUC of 0.836 (95% CI, 0.767–0.891), but the ideal cutoff point to detect MetS (≥9.88) was higher than the value determined in our results (≥ 8.61).

Furthermore, according to the IDF criteria [23], our results indicated a higher AUC TyG index (0.877; 95% CI, 0.814–0.940) than the AUC found in a study performed in Pakistan (AUC = 0.764 [95% CI, 0.700–0.828; $P \leq 0.001$]) [14].

Data using the NCEP/ATP III MetS criteria [25] revealed a cutoff point higher than the other criteria analyzed for the TyG index (≥8.79), sensitivity (77.4%), and specificity (79.4%), and AUC (0.867; 95% CI, 0.797–0.937). These data are in accordance with those found by Unger et al. [15] in workers in Argentina, indicating a TyG index value of 8.8 for both sexes, with perfect sensitivity (79%) and specificity (86%). In addition, a Korean study [34] with a rural population of normal weight has identified metabolic risk ranging from cutoff points 8.73 to 8.82 for both men and women.

The higher AUC and the lower cutoff point of the TyG index found in our study may be because our sample was composed of

Table 2
TyG index values according to three metabolic syndromes' diagnostic criteria

TyG index criteria	Metabolic syndrome		P^*	PR	95% CI		$P^\dagger$
	No Mean ± SD	Yes Mean ± S D			Lower	Upper	
Harmonized	8.49 ± 0.30	9.08 ± 0.41	< 0.001	6.009	3.899	9.261	< 0.001
IDF	8.51 ± 0.34	9.05 ± 0.37	< 0.001	5.450	3.145	9.446	< 0.001
NCEP/ATPIII	8.53 ± 0.33	9.08 ± 0.41	< 0.001	6.124	3.819	9.820	< 0.001

Harmonized, criteria of American Heart Association/National Heart, Lung, and Blood Institute and IDF; IDF, International Diabetes Federation; NCEP/ATPIII, revised criteria of the National Cholesterol Education Program Adult Treatment Panel III; PR, prevalence ratio; TyG, triglyceride-glucose

*Student's t test.

†Poisson regression, adjusted for age, sex, and education.

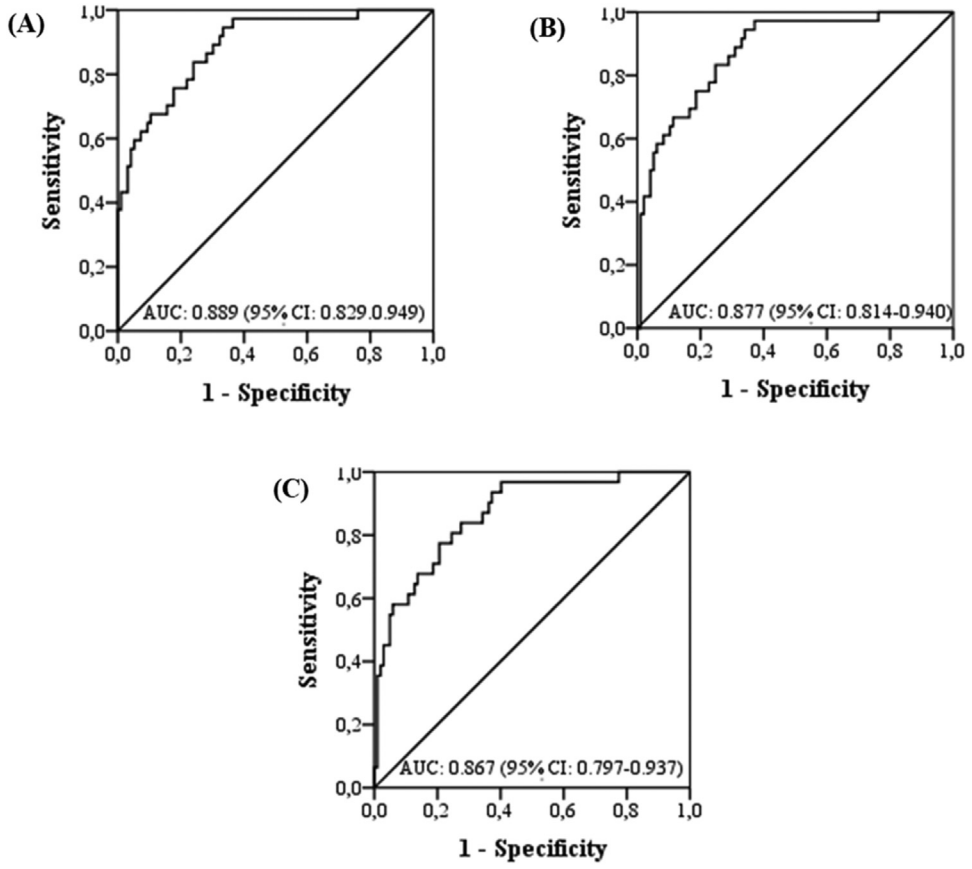

Fig. 1. Receiver operating characteristic (ROC) curve of the TyG index (the test variable) for predicting metabolic syndrome (the state variable) diagnosed through the following criteria: (A) harmonized criteria of American Heart Association/National Heart, Lung, and Blood Institute and International Diabetes Federation; (B) International Diabetes Federation; and (C) revised criteria of the National Cholesterol Education Program Adult Treatment Panel III in the total sample. AUC, area under the curve.

individuals without type 2 diabetes mellitus who did not use drugs that interfere with glucose metabolism and insulin resistance.

Several studies have determined cutoff points for the TyG index in identifying insulin resistance [11,29,30,35,36] and MetS [13,14,16] in different populations. In a systematic review, Nabipoorashrafi et al. [37] investigated the accuracy of TyG index for MetS in adults. The investigators concluded that the TyG index is a sensitive and specific index [37]. However, few studies have addressed the performance of the TyG index to predict MetS in individuals living in rural areas without a diagnosis of diabetes mellitus [18,34]. The use of different criteria to define MetS, which differ mainly in the parameters of elevated waist circumference in different populations and other pathological conditions such as dyslipidemia, may influence the TyG index in identifying MetS. However, glucose and lipid abnormalities may play a crucial role in the pathogenesis of MetS [33].

The major strength of this study is the relevance regarding the prediction of MetS in individuals living in rural areas without a diagnosis of diabetes mellitus. Accuracy studies of the TyG index in identifying MetS are still scarce in Brazil, especially in the rural population. In this context, the TyG index had a good performance as a surrogate marker for MetS. The TyG index is a simple and inexpensive index that can be useful for different health care settings such as primary health care, because it only requires fasting glucose and triglyceride results.

Table 3
Cutoff points, sensitivity, specificity, positive predictive value, and negative predictive value of the TyG index to predict metabolic syndrome

Índex	Altered TyG *n* (%)	Metabolic syndrome		SE	SP	PPV	NPV
		No *n* (%)	Yes *n* (%)				
Harmonized							
TyG ≥ 8.61	67 (50.4)	32 (33.3)	35 (94.6)	0.946	0.667	0.522	0.970
IDF							
TyG ≥ 8.61	67 (50.4)	33 (34.0)	34 (94.4)	0.944	0,660	0.507	0.970
NCEP/ATPIII							
TyG ≥ 8.79	45 (33.8)	21 (20.6)	24 (77.4)	0.774	0.794	0.533	0.920

Harmonized, criteria of the American Heart Association/National Heart, Lung, and Blood Institute and IDF; IDF, International Diabetes Federation; NCEP/ATPIII, National Cholesterol Education Program Adult Treatment Panel III; NPV, negative predictive value; TyG: triglyceride-glucose; PPV, positive predictive value; SE, sensitivity; SP, specificity
Criteria cutoff point determined according to Youden index.

Individuals residing in a rural environment have specific characteristics of that environment, such as lower socioeconomic and educational levels and difficulties in obtaining access to health services, due to low demographic density and dispersed population [38]. Health policy for rural populations aims to reduce health problems for rural workers, but with actions aimed at work processes [39]. Many rural communities still do not have health facilities in their territory, having to seek care in urban areas. However, early identification of cardiometabolic risk factors enables prevention of cardiovascular and metabolic diseases, contributing to successful aging and better quality of life.

The TyG index is a simple and low-cost tool that includes only two routine biochemical measurements (triglycerides and glucose) from clinical practice and is effective in identifying MetS. However, to our knowledge, no other study has evaluated the prevalence of MetS in individuals from rural areas without a diagnosis of diabetes mellitus and the performance of TyG in identifying MetS through different criteria. The main limitation of the present study was its cross-sectional design, with inherent limitations. Future studies should be performed to better estimate the performance of the TyG index in predicting other cardiometabolic diseases.

Conclusions

The TyG index proved valid for diagnosing MetS in individuals from rural areas. The TyG index cutoff points defined for the harmonized and IDF criteria were $\geq$ 8.61 and for the revised NCEP/ATPIII criteria $\geq$ 8.79. The largest AUC TyG index was identified for the harmonized criteria.

Acknowledgments

We would like to thank Dr. Miriam Beatris Reckziegel and the team from the Physical Activity and Health Laboratory (LAFISA) and Dr. Jane Dagmar Pollo Renner, in charge of the Exercise Biochemistry Laboratory of the University of Santa Cruz do Sul.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.nut.2023.111978.

References

[1] Saad MAN, Cardoso GP, Martins WA, Velarde LGC, Cruz-Filho RA. Prevalence of metabolic syndrome in elderly and agreement among four diagnostic criteria. Arq Bras Cardiol 2014;110:263–9.
[2] Alberti KGMM, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, Donato KA, et al. Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. Circulation 2009;120:1640–5.
[3] Khan Y, Lalchandani A, Gupta AC, Khadanga S, Kumar S. Prevalence of metabolic syndrome crossing 40% in Northern India: Time to act fast before it runs out of proportions. J Family Med Prim Care 2018;7:118–23.
[4] Siqueira Valadares LT, Souza LSB, Salgado Júnior VA, Bonomo LF, Macedo LR, Silva M. Prevalence of metabolic syndrome in Brazilian adults in the last 10 years: a systematic review and meta-analysis. BMC Public Health 2022;22:327.
[5] O'Neill S, O'Driscoll L. Metabolic syndrome: a closer look at the growing epidemic and its associated pathologies. Obes Rev 2015;16:1–12.
[6] Auro K, Joensuu A, Fischer K, Kettunen J, Salo P, Mattsson H, et al. A metabolic view on menopause and ageing. Nat Commun 2014;5:1–11.
[7] Newgard CB, Pessin JE. Recent progress in metabolic signaling pathways regulating aging and life span. J Gerontol A Biol Sci Med Sci 2014;69:S21–7.
[8] Salaroli LB, Cattafesta M, Molina MCB, Zandonade E, Bissoli NS. Insulin resistance and associated factors: a cross-sectional study of bank employees. Clinics 2017;72:224–30.
[9] Sociedade Brasileira de Diabetes. Diretrizes da Sociedade Brasileira de Diabetes: 2019−2020. São Paulo, Brazil: Editora Clannad; 2020.
[10] Simental-Mendía LE, Rodríguez-Morán M, Guerrero-Romero F. The product of fasting glucose and triglycerides as surrogate for identifying insulin resistance in apparently healthy subjects. Metabolic Syndr Relatory Disord 2008;6:229–304.
[11] Du T, Yuan G, Zhang M, et al. Clinical usefulness of lipid ratios, visceral adiposity indicators, and the triglycerides and glucose index as risk markers of insulin resistance. Cardiovasc Diabetol 2014;13:146.
[12] Shin KA, Kim YJ. Usefulness of surrogate markers of body fat distribution for predicting metabolic syndrome in middle-aged and older Korean populations. Diabetes Metab Syndr Obes 2019;12:2251–9.
[13] Raimi TH, Dele-Ojo BF, Dada SA, Fadare JO, Ajayi DD, Ajayi EA, et al. Triglyceride-glucose index and related parameters predicted metabolic syndrome in Nigerians. Metab Syndr Relat Disord 2021;19:76–82.
[14] Khan SH, Sobia F, Niazi NK, Manzoor SM, Fazal N, Ahmad F. Metabolic clustering of risk factors: evaluation of triglyceride-glucose index for evaluation of insulin resistance. Diabetol Metab Syndr 2018;10:74.
[15] Unger G, Benozzi SF, Perruzza F, Pennacchiotti GL. Triglycerides and glucose index: a useful indicator of insulin resistance. Endocrinol Nutr 2014;61:533–40.
[16] Li R, Li Q, Cui M, Yin Z, Li L, Zhong T, et al. Clinical surrogate markers for predicting metabolic syndrome in middle-aged and elderly Chinese. J Diabetes Investig 2018;9:411–8.
[17] Arruda NM, Maia AG, Alves LC. Inequality in access to health services between urban and rural areas in Brazil: a disaggregation of factors from 1998 to 2008. Cad Saúde Pública 2018;34:e00213816.
[18] Zhang M, Wang B, Liu Y, Sun X, Luo X, Wang C, et al. Cumulative increased risk of incident type 2 diabetes mellitus with increasing triglyceride glucose index in normal-weight people: the Rural Chinese Cohort Study. Cardiovasc Diabetol 2017;16:30.
[19] Moreira JPL, Oliveira BLCA, Muzi CD, Cunha CLF, Brito AS, Luiz RR. Rural workers' health in Brazil Cad Saúde. Pública 2015;31:1698–708.
[20] Oliveira EP, Souza MLA, Lima MDA. Prevalence of metabolic syndrome in a semi-arid rural area in Bahia. Arq Bras Endocrinol Metab 2006;50:456–65.
[21] Pimenta AM, Gazzinelli A, Velásquez-Meléndez G. Prevalence of metabolic syndrome and its associated factors in a rural area of Minas Gerais State. Ciênc Saúde Coletiva 2011;16:3297–306.
[22] Leite MM, Dutra MT, Costa MVG, Funghetto SS, Silva AO, Lima LR, et al. Comparative evaluation of inflammatory parameters and substitute insulin resistance indices in elderly women with and without type 2 diabetes mellitus. Exp Gerontol 2021;15:111389.
[23] National Institutes of Health; National Heart, Lung, and Blood Institute; North American Association for the Study of Obesity. The practical guide: identification, evaluation, and treatment of overweight and obesity in adults. Available at: https://books.google.com.br/books?hl=pt-BR&lr=&id=JR8DhPHpC_AC&oi=fnd&pg=PR5&ots=48IGgo-d1O&sig=kz84KA7IliKJ12w70-Sc8QZSdvs&redir_esc=y#v=onepage&q&f=false. Accessed December 20, 2020.
[24] Alberti KGMM, Zimmet P, Shaw J. IDF Epidemiology Task Force Consensus Group. The metabolic syndrome—a new worldwide definition. Lancet 2005;366:1059–62.
[25] Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute scientific statement. Circulation 2005;112:2735–52. [errata: e297, e298].
[26] Wians FH. Clinical laboratory tests: which, why, and what do the results mean? Lab Med 2009;40:105–13.
[27] Youden WJ. Index for rating diagnostic tests. Cancer 1950;3:32–5.
[28] Cohen JF, Korevaar DA, Altman DG, Bruns DE, Gatsonis CA, Hooft L, et al. STARD 2015 guidelines for reporting diagnostic accuracy studies: explanation and elaboration. BMJ Open 2016;6:e012799.
[29] Guerrero-Romero F, Simental-Mendía LE, González-Ortiz M, Martínez-Abundis E, Ramos-Zavala MG, Hernández-González SO, et al. The product of triglycerides and glucose, a simple measure of insulin sensitivity: comparison with the euglycemic-hyperinsulinemic clamp. J Clin Endocrinol Metab 2010;95:3347–51.
[30] Vasques ACJ, Novaes FS, Oliveira MS, Souza JRM, Yamanaka A, Pareja JC, et al. TyG index performs better than HOMA in a Brazilian population: a hyperglycemic clamp validated study. Diabetes Res Clin Pract 2011;93:e98–100.
[31] Sociedade Brasileira de Diabetes. Diretrizes da Sociedade Brasileira de Diabetes: 2013−2014. São Paulo, Brazil: AC Farmacêutica; 2014.
[32] Yu X, Wang L, Zhang W, Ming J, Jia A, Xu S, et al. Fasting triglycerides and glucose index is more suitable for the identification of metabolically unhealthy individuals in the Chinese adult population: a nationwide study. J Diabetes Investig 2019;10:1050–8.
[33] Endukuru CK, Gaur GS, Yerrabelli D, Sahoo J, Vairappan B. Cut-off values and clinical utility of surrogate markers for insulin resistance and beta-cell function to identify metabolic syndrome and its components among southern Indian adults. J Obes Metab Syndr 2020;29:281–91.
[34] Lee SH, Han K, Yang HK, Kim HS, Cho JH, Kwon HS, et al. A novel criterion for identifying metabolically obese but normal weight individuals using the product of triglycerides and glucose. Nutr Diabetes 2015;5:e149.
[35] Gastaldelli A, Folli F, DeFronzo RA. The product of triglycerides and glucose as index of insulin resistance. Validation in the SAM study. J Clin Endocrinol Metab 2010;95:3351.
[36] Espinel-Bermúdez MC, Robles-Cervantes JA, Del Sagrario Villarreal-Hernández L, Villaseñor-Romero JP, Hernández-González SO, et al. Insulin resistance in

adult primary care patients with a surrogate index, Guadalajara, Mexico, 2012. J Investig Med 2015;63:247–50.
[37] Nabipoorashrafi SA, Seyedi SA, Rabizadeh S, Ebrahimi M, Ranjbar SA, Reyhan SK, et al. The accuracy of triglyceride-glucose index for the screening of metabolic syndrome in adults: A systematic review and metaanalysis. Nutr Metab Cardiovasc Dis 2022;32:2677–88.
[38] Sakamoto E, Lima JP. Acessibilidade em ambientes rural: uma abordagem com uso de SIG. Transportes 2016;24:63–73.
[39] Ministério da Saúde, Brasil. Saúde e ambientes para as populações do campo das florestas e das águas. Brasília - DF. Available at: https://bvsms.saude.gov.br/bvs/publicacoes/saude_ambiente_populacoes_campo_floresta_aguas.pdf. Accessed December 20, 2020.