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Triglyceride Glucose-Waist Circumference Is Superior to Other Biochemical Indicators for Diagnosing Prehypertension and Hypertension

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Abstract

Background: In situations with economic issues and limited resources, prevention and early detection of hypertension are essential for its control. Diagnosis and treatment require considerable expenses, which could lead to an incomplete diagnosis and, therefore, a higher prevalence. The aim of this study was to evaluate the usefulness of eight biochemical indices as diagnostic tools for prehypertension and hypertension.

Methods: This is a diagnostic testing study. The variables were hypertension and prehypertension. Among the markers evaluated were triglycerides/high-density lipoprotein cholesterol (HDL-C), cholesterol/HDL-C, low-density lipoprotein (LDL)/HDL-C, visceral adiposity index, lipid accumulation product, the triglyceride-glucose (TyG) index, TyG-waist circumference (TyG-WC), and TyG-body mass index (TyG-BMI). The receiver operating characteristic (ROC) curve analysis was used as a statistical and graphical method to evaluate diagnostic capacity, as well as the area under the curve (AUC) corresponding to each response variable. Sensitivity (Se) and specificity (Sp) were calculated, along with their 95% confidence intervals (95% CIs).

Results: The prevalence of undiagnosed prehypertension and hypertension was 6.88% and 2.72%, respectively. The TyG-WC has been the best indicator for both prehypertension: AUC = 0.712 (95% CI: 0.650 - 0.775), cutoff = 762.56, Se = 90.74 (95% CI: 79.70 - 96.92), and Sp = 45.24 (95% CI: 41.61 - 48.92), in terms of diagnostic capacity. The same applies to hypertension: AUC = 0.801 (95% CI: 0.718 - 0.883), cutoff = 862.57, Se = 81.81 (95% CI: 59.72 - 94.81), and Sp = 70.18 (95% CI: 66.84 - 73.35).

Conclusions: The TyG-WC is the best diagnostic tool for prehypertension and hypertension; hence, it is necessary to conduct prospective research to verify these findings. If confirmed, the TyG-WC can be used as a marker for the prognosis of these two conditions and, thus, to make decisions about prevention.

Keywords: Prehypertension; Hypertension; Waist circumference; Triglycerides; Glucose

Introduction

Hypertension (HTN) is characterized by high systolic blood pressure (SBP) and/or diastolic blood pressure (DBP) and constitutes a major public health issue globally [1]. Between 20% and 40% of female and male patients respectively have HTN in Latin America [2, 3]. In Peru, 17.4% of those aged 15 and over have high blood pressure [4].

Covering the costs for diagnosis and treatment of HTN and its associated complications can be expensive; this could lead to insufficient diagnosis and ultimately, a higher prevalence of the disease [5]. Early detection and prevention are vital for control, especially when resources are limited [6, 7].

The use of simple and reliable markers that combine laboratory analyses or anthropometric measurements have been considered as potential contributors in the early and efficient detection of HTN. This facilitates the inclusion of precise preventive and therapeutic measures [8-10]. Likewise, the use of markers could contribute to an optimal understanding of underlying pathophysiological mechanisms and the evaluation of associated risk. This improves the clinical management of users and improves public health outcomes. While some markers have shown long-term diagnostic or associative power, others have not had successful results [10-16]. Moreover, the choice of cut-off points is still problematic, as there is still a lack of evidence in Latin American populations.

Given this, the present study aimed to evaluate the usefulness of eight biochemical indices as diagnostic tools for prehypertension and HTN.

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Materials and Methods

Study design and context

This is a diagnostic test study. The analysis is secondary to the data from the 2017 - 2018 Surveillance Survey of Nutrition and Food by Life Stages (VIANEV), which was prepared by the National Center for Food and Nutrition (CENAN) in Peru [17]. The STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines [18] and the STARD (Standards for Reporting of Diagnostic Accuracy Studies) statement [19] have been considered.

Population, sample, and eligibility criteria

The 2017 - 2018 VIANEV survey contains data from three areas: Metropolitan Lima (the Peruvian capital), as well as other urban and rural areas, and for this, a stratified, random, multistage, and independent sampling method was used [17]. The sample was obtained in two phases: the primary sampling unit was randomly chosen clusters, while the secondary sampling covered randomly selected households with adults aged 18 to 59 years who had fasted for 9 to 12 h. The VIANEV survey's sample base was formed by households included in the National Household Survey (ENAHO), which covered 1,296 clusters (176 in Metropolitan Lima and Callao, 696 in other urban areas, and 424 in rural areas). The inference was executed in Peru, in the urban, rural sector, and in Metropolitan Lima (capital of Peru). More details about the methodology can be found in the Technical Report of the 2017 - 2018 VIANEV survey and in previous research [17].

In this work, those with the study variables were included. Meanwhile, patients with a previous diagnosis of HTN or prehypertension were discarded.

Definition of variables

The response variables were: 1) HTN, which was defined if they presented any of the following conditions: SBP $\geq$ 140 mm Hg or DBP $\geq$ 90 mm Hg [20]; and 2) prehypertension, which was defined if they presented: SBP $\geq$ 120 - 139 mm Hg or DBP $\geq$ 80 - 89 mm Hg.

The biomarkers that were put to the test were:

Triglycerides/high-density lipoprotein cholesterol (HDL-C) = triglycerides (mg/dL)/HDL-C (mg/dL)

Cholesterol/HDL-C = total cholesterol (mg/dL)/HDL-C (mg/dL)

Low-density lipoprotein (LDL)/HDL-C = LDL cholesterol mg/dL)/HDL-C (mg/dL)

Visceral adiposity index$_{women}$ = waist circumference (WC)/(36.58 + (1.89 × body mass index (BMI)) × (triglyceride/0.81) × (1.52/HDL-C)

Visceral adiposity index$_{men}$ = WC/(39.68 + (1.88 × BMI)) × (triglycerides/1.03) × (1.31/HDL-C)

Lipid accumulation product$_{women}$ = (WC - 58) × triglycerides

Lipid accumulation product$_{men}$ = (WC - 65) × triglycerides

Triglyceride-glucose (TyG) = Ln (triglycerides (mg/dL) × fasting glucose (mg/dL)/2)

TyG-WC = Ln (triglycerides (mg/dL) × fasting glucose (mg/dL)/2) × WC

TyG-BMI = Ln (triglycerides (mg/dL) × fasting glucose (mg/dL)/2) × BMI

The covariates considered for statistical adjustment were sex (male, female), age group (categorized in 18 - 29, 30 - 39 years, 40 - 49 years, and 50 - 59 years), educational level (up to primary, secondary, high), marital status (single, with a partner), natural region (Metropolitan Lima, rest of the coast, mountains, and jungle), area of residence (urban, rural), alcohol consumption in the last 30 days (yes, no), current smoking status (yes, no), socioeconomic status (poor, not poor) and physical activity (low, medium, high).

Data collection and procedure

A digital sphygmomanometer was used to measure blood pressure. First, to take the measure, the patient's dominant arm was chosen. Subsequently, two measurements of blood pressure were taken, and the average was calculated to determine a preliminary diagnosis. If a difference of 20 mm Hg between the first and second measurement of the SBP or 10 mm Hg between the first and second of the DBP was detected, a third was decided. The measurements that did not show such differences were recorded. Blood pressure was taken mostly in the morning, between 6:00 am and 9:00 am.; if not possible, it was done between 7:00 pam and 9:00 pm.

The patient needed to be fasting for a period between 9 and 12 h. For the laboratory analyses, the serum was extracted and transported in a cold chain to establish the lipid profile. Triglyceride levels were measured through an enzymatic-colorimetric method of automatic coupled endpoint reactions, while to establish blood glucose levels, portable glucometers (HemoCue Glucose 201 RT) were used, which had been correctly calibrated. HDL-C and LDL were determined by the automated direct enzymatic-colorimetric method.

The BMI was obtained by dividing the weight in kg by the square of the height in m. The abdominal perimeter was measured at the end of exhalation with a tape measure, while the patient stood with bare torso and feet separated between 25 and 30 cm, at the height of the upper edge of the iliac crest. This was applied three continuous times, and the average of the measurements was considered as the result.

Statistical analysis

Statistical analyses were executed using R software version 4.0.5. First, a descriptive analysis was developed, summarizing categorical variables in absolute terms and percentages, and numerical ones, using mean and standard deviation (SD). To identify differences between groups, according to BMI, in the bivariate analysis, the Rao-Scott Chi-square test was used for categorical variables and the F test for numerical ones, which showed a normal distribution evaluated by skewness, kurtosis, and histogram analysis.

The receiver operating characteristic (ROC) curves analysis was used as a statistical and graphic method, as well as the area under the curve (AUC) that corresponds to each response variable, to measure the diagnostic ability. Sensitivity (Se), specificity (Sp), positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (PLR), and negative likelihood ratio (NLR) were calculated. The Youden index was used to establish the optimal cut-off point. Each value was presented with its respective 95% confidence interval (95% CI). Analyses were made according to sample weights.

Finally, each index was divided into tertiles, and a bivariate and multivariable Poisson regression analysis with robust variance was performed for each response variable. These are included in the multivariable model: age, sex, cigarette smoking, alcohol consumption, and physical activity. The measure of association was the crude prevalence ratio (cPR) and adjusted prevalence ratio (aPR) with a 95% confidence interval (95% CI). A statistically significant value of $P < 0.05$ was considered.

Ethical aspects

The research adhered to the ethical guidelines set forth by the overseeing institution concerning human participants and was in alignment with the Helsinki Declaration. The survey is available free of charge [17]. To ensure respondent confidentiality, the database was encrypted, preventing the disclosure of participants' full names. Given these precautions, an ethical review was deemed unnecessary.

Results

The prevalence of prehypertension and undiagnosed HTN was 6.88% and 2.72%, respectively. Females constituted 55.31% of the sample. Only 32.35% resided in rural areas. Regarding harmful habits, 49.88% had consumed alcohol in the past 30 days, while only 13.46% smoked daily. The rest of the univariate and bivariate analyses can be seen in Table 1.

There was a statistically significant association between TyG-WC and prehypertension in the third tertile (adjusted odds ratio (aOR) = 7.60; 95% CI: 2.44 - 33.7) in the multivariable analysis. The same is true for TyG-WC and HTN (aOR = 9.62; 95% CI: 1.66 - 186). The other analyses can be seen in Table 2.

The TyG-WC has been the best indicator for both prehypertension: AUC = 0.712 (95% CI: 0.650 - 0.775), cutoff = 762.56, Se = 90.74 (95% CI: 79.70 - 96.92), and Sp = 45.24 (95% CI: 41.61 - 48.92) regarding the diagnostic capacity. The same happens with HTN: AUC = 0.801 (95% CI: 0.718 - 0.883), cutoff = 862.57, Se = 81.81 (95% CI: 59.72 - 94.81), and Sp = 70.18 (95% CI: 66.84 - 73.35). The rest of the data can be seen in Table 3 and Figure 1.

Discussion

Main findings

In this study, aimed at determining the best biochemical and/or anthropometric indicator as a diagnostic marker of HTN, we found that the TyG-WC index was the best indicator analyzed, especially for prehypertension and HTN. It is noteworthy that this is the first study in Peru that evaluates this subject.

Comparison with other studies

The TyG index has been confirmed to date as closely related to the traditional risk factors of cardiovascular diseases (CVDs) [21-23], including HTN [10, 24]. On the other hand, WC has also been recognized as an excellent indicator of high blood pressure [25, 26]. Therefore, their combination may be a precise indicator of this disease.

It has been demonstrated that TyG-WC is very useful in other pathologies, such as insulin resistance [27, 28], fatty liver, and type 2 diabetes mellitus [29, 30]. However, while many studies have determined the relationship between TyG [13] and prehypertension/HTN, few have established the relationship between TyG-WC, and those that have done so have had controversial results. For instance, in the study by Bala et al [14], it was found that this indicator is not superior to others. Meanwhile, Yuan et al [15] found that TyG-WC had the best diagnostic capacity. Although Zeng et al [16] concluded that TyG-BMI was the best through AUC, it should be noted that the difference with TyG-WC was nearly a tenth.

Regarding studies that determined prehypertension, none were found to do so directly with TyG-WC. Research such as that by Zeng et al [16] showed a positive correlation between TyG-BMI and prehypertension; Zhang et al [31] found that TyG was superior to other markers such as triglycerides/HDL-C. However, there are still controversies, as Zhang et al [32] or Fan et al [33] found that metabolic score for insulin resistance (METS-IR) index was a better indicator than the others. These controversies create the need for further research on these pathologies.

Interpretation of results

The pathophysiology of HTN is complex and involves various mechanisms and systems that interact with each other. A significant factor in HTN is insulin resistance, a state in which the body's cells are less sensitive to its action, resulting in increased blood glucose levels. Insulin resistance can also cause an increase in the production of triglycerides and free fatty acids, which could directly affect the function and structure of blood vessels, as well as increase sodium and water retention in the kidneys; this leads to an increase in blood volume and blood pressure [34, 35].

Another crucial factor in HTN is endothelial dysfunction,

Table 1. Descriptive and Bivariate Characteristics According to the Presence of Prehypertension/Hypertension

Characteristic		Undiagnosed prehypertension			Undiagnosed hypertension		
		No, n = 736	Yes, n = 54	P value[a]	No, n = 788	Yes, n = 22	P value[a]
Sex							
Female	448 (55.31%)						
Male	362 (44.69%)						
Age group				< 0.001*			0.014*
18 to 29 years old	237 (29.26%)	230 (97.87%)	5 (2.13%)		235 (99.16%)	2 (0.84%)	
30 to 39 years old	214 (26.42%)	202 (95.73%)	9 (4.27%)		210 (98.13%)	4 (1.87%)	
40 to 49 years old	198 (24.44%)	174 (90.62%)	18 (9.38%)		192 (96.97%)	6 (3.03%)	
50 to 59 years old	161 (19.88%)	130 (85.53%)	22 (14.47%)		151 (93.79%)	10 (6.21%)	
Civil status				0.255			0.354
Single	297 (36.67%)	275 (94.50%)	16 (5.50%)		291 (97.98%)	6 (2.02%)	
With couple	513 (63.33%)	461 (92.38%)	38 (7.62%)		497 (96.88%)	16 (3.12%)	
Educational level				0.433			0.294
Higher	318 (39.41%)	291 (92.97%)	22 (7.03%)		313 (98.43%)	5 (1.57%)	
Secondary	314 (38.91%)	282 (92.16%)	24 (7.84%)		304 (96.82%)	10 (3.18%)	
Until primary	175 (21.69%)	161 (95.27%)	8 (4.73%)		169 (96.57%)	6 (3.43%)	
Natural region				0.967			0.129
Jungle	118 (14.57%)	105 (93.75%)	7 (6.25%)		111 (94.07%)	7 (5.93%)	
Metropolitan Lima	383 (47.28%)	350 (93.33%)	25 (6.67%)		375 (97.91%)	8 (2.09%)	
Mountain range	143 (17.65%)	131 (92.25%)	11 (7.75%)		141 (98.60%)	2 (1.40%)	
Rest of coast	166 (20.49%)	150 (93.17%)	11 (6.83%)		161 (96.99%)	5 (3.01%)	
Area of residence				0.848			0.328
Rural	262 (32.35%)	241 (93.41%)	17 (6.59%)		257 (98.09%)	5 (1.91%)	
Urban	548 (67.65%)	495 (93.05%)	37 (6.95%)		531 (96.90%)	17 (3.10%)	
Wealth index				0.126			0.402
No poor	659 (81.36%)	592 (92.50%)	48 (7.50%)		639 (96.97%)	20 (3.03%)	
Poor	151 (18.64%)	144 (96.00%)	6 (4.00%)		149 (98.68%)	2 (1.32%)	
Alcohol consumption				0.560			0.657
No	406 (50.12%)	371 (93.69%)	25 (6.31%)		396 (97.54%)	10 (2.46%)	
Yes	404 (49.88%)	365 (92.64%)	29 (7.36%)		3920 (97.03%)	12 (2.97%)	
Daily smoking				0.755			0.945
No	701 (86.54%)	638 (93.27%)	46 (6.73%)		682 (97.29%)	19 (2.71%)	
Yes	109 (13.46%)	98 (92.45%)	8 (7.55%)		106 (97.25%)	3 (2.75%)	
Physical activity				0.787			0.978
High	114 (14.07%)	104 (93.69%)	7 (6.31%)		111 (97.37%)	3 (2.63%)	
Low	537 (66.30%)	485 (92.73%)	38 (7.27%)		522 (97.21%)	15 (2.79%)	
Moderate	159 (19.63%)	147 (94.23%)	9 (5.77%)		155 (97.48%)	4 (2.52%)	
Triglycerides/HDL-C ratio	5.0 (4.9)	4.9 (4.8)	7.1 (5.6)	0.006*	5.0 (4.9)	6.4 (4.1)	0.131
Cholesterol/HDL-C ratio	5.19 (2.03)	5.10 (1.98)	6.06 (2.14)	0.002*	5.16 (2.01)	6.22 (2.40)	0.054
LDL/HDL-C ratio	3.22 (1.44)	3.17 (1.41)	3.65 (1.44)	0.021*	3.20 (1.42)	3.93 (1.82)	0.076
Visceral adiposity index	2.84 (2.82)	2.72 (2.76)	4.13 (3.34)	0.004*	2.82 (2.83)	3.72 (2.42)	0.100
Lipid accumulation product	54 (46)	51 (45)	79 (57)	0.001*	53 (46)	86 (44)	0.002*
TyG index	8.84 (0.60)	8.80 (0.59)	9.10 (0.60)	< 0.001*	8.82 (0.60)	9.28 (0.62)	0.003*
TyG-BMI index	239 (51)	236 (50)	265 (48)	< 0.001*	238 (50)	290 (60)	< 0.001*
TyG-WC index	801 (136)	790 (132)	889 (133)	< 0.001*	797 (134)	948 (122)	< 0.001*

Data were shown as n (%), and mean (SD). [a]Rao-Scott Chi-square and the F test. *P < 0.05. HDL-C: high-density lipoprotein cholesterol; LDL: low-density lipoprotein; TyG: triglyceride-glucose; TyG-WC: TyG-waist circumference; TyG-BMI: TyG-body mass index; SD: standard deviation.

Table 2. Multivariable Regression Analysis of Eight Biochemical Indicators Divided Into Tertiles for Prehypertension/Hypertension

Characteristic	Prehypertension			Hypertension		
	aOR[a]	95% CI	P value	aOR[a]	95% CI	P value
Triglycerides/HDL-C ratio						
Tertile 1	Ref.			Ref.		
Tertile 2	1.4	0.59 - 3.47	0.452	1	0.27 - 4.09	0.995
Tertile 3	2.69	1.24 - 6.36	0.017*	1.49	0.45 - 5.85	0.531
Cholesterol/HDL-C ratio						
Tertile 1	Ref.			Ref.		
Tertile 2	1.02	0.44 - 2.42	0.955	2.05	0.54 - 9.92	0.319
Tertile 3	2.03	0.98 - 4.50	0.066	2.14	0.60 - 10.1	0.273
LDL/HDL-C ratio						
Tertile 1	Ref.			Ref.		
Tertile 2	1.47	0.67 - 3.36	0.344	1.81	0.46 - 8.92	0.419
Tertile 3	1.65	0.77 - 3.70	0.208	2.41	0.69 - 11.3	0.202
Visceral adiposity index						
Tertile 1	Ref.			Ref.		
Tertile 2	1.44	0.62 - 3.56	0.405	0.82	0.21 - 3.47	0.778
Tertile 3	2.48	1.13 - 5.91	0.029*	1.63	0.50 - 6.35	0.439
Lipid accumulation product						
Tertile 1	Ref.			Ref.		
Tertile 2	3.19	1.22 - 9.96	0.027*	1.57	0.31 - 11.5	0.606
Tertile 3	3.74	1.45 - 11.7	0.012*	3.73	0.92 - 25.4	0.103
TyG index						
Tertile 1	Ref.			Ref.		
Tertile 2	1.29	0.56 - 3.09	0.553	2.1	0.45 - 14.8	0.379
Tertile 3	2.18	1.01 - 5.02	0.054	3.59	0.90 - 24.1	0.108
TyG-BMI index						
Tertile 1	Ref.			Ref.		
Tertile 2	5.03	1.82 - 17.8	0.004*	1.76	0.36 - 12.8	0.512
Tertile 3	5.52	1.99 - 19.7	0.003*	4.39	1.07 - 30.1	0.069
TyG-WC index						
Tertile 1	Ref.			Ref.		
Tertile 2	5.42	1.74 - 23.9	0.009*	1.66	0.19 - 35.2	0.670
Tertile 3	7.60	2.44 - 33.7	0.002*	9.62	1.66 - 186	0.039*

[a]Adjusted for sex, age group, marital status, educational level, natural region, area of residence, socioeconomic level, alcohol consumption in the last 30 days, current smoker, and physical activity. *P < 0.05. aOR: adjusted odds ratio; CI: confidence interval; Ref: reference; HDL-C: high-density lipoprotein cholesterol; LDL: low-density lipoprotein; TyG: triglyceride-glucose; TyG-WC: TyG-waist circumference; TyG-BMI: TyG-body mass index.

which refers to an alteration in the function of the endothelium, the layer of cells lining the inside of blood vessels. The endothelium plays a significant role in vascular tone regulation and homeostasis and releases vasoactive substances like nitric oxide (NO), leading to the relaxation of blood vessels and a decrease in blood pressure. Endothelial dysfunction could result from risk factors like obesity, insulin resistance, and metabolic syndrome, and it could contribute to the development of HTN by causing a decrease in NO production and an increase in the production of vasoconstrictor substances [36, 37].

Activation of the renin-angiotensin-aldosterone system (RAAS) also plays a crucial role in the pathophysiology of HTN. The RAAS is a hormonal system that helps regulate blood pressure and the balance of fluids and electrolytes in the body. Excessive or inappropriate activation of the RAAS may result in the constriction of blood vessels, retention of sodium and water in the kidneys, and stimulation of the sympathetic

Table 3. Diagnostic Capacity of Each Biochemical Indicator for Prehypertension/Hypertension

	Cutoffs	AUC	Se (%)	Sp (%)	PPV (%)	NPV (%)	LR+ (%)	LR- (%)
Prehypertension								
Triglycerides/HDL-C ratio	3.95	0.656 (0.581 - 0.732)	68.52 (54.44 - 80.47)	58.96 (55.32 - 62.55)	10.91 (9.55 - 18.83)	96.23 (93.34 - 96.74)	1.67 (1.37 - 2.04)	0.53 (0.36 - 0.79)
Cholesterol/HDL-C ratio	4.82	0.649 (0.573 - 0.724)	75.92 (62.36 - 86.51)	52.71 (49.03 - 56.37)	10.54 (9.22 - 19.33)	96.76 (94.00 - 97.19)	1.61 (1.36 - 1.90)	0.45 (0.28 - 0.74)
LDL/HDL-C ratio	3.46	0.610 (0.534 - 0.685)	53.70 (39.61 - 67.38)	66.71 (63.18 - 70.11)	10.58 (9.20 - 17.41)	95.16 (91.74 - 95.81)	1.61 (1.23 - 2.11)	0.69 (0.52 - 0.93)
Visceral adiposity index	2.35	0.666 (0.592 - 0.740)	66.67 (52.53 - 78.91)	62.09 (58.48 - 65.61)	11.43 (9.99 - 19.44)	96.21 (93.35 - 96-73)	1.76 (1.43 - 2.17)	0.53 (0.37 - 0.79)
Lipid accumulation product	34.8	0.678 (0.611 - 0.746)	85.19 (72.88 - 93.38)	47.28 (43.62 - 50.96)	10.59 (9.28 - 22.53)	97.75 (95.31 - 98.05)	1.61 (1.42 - 1.84)	0.31 (0.16 - 0.69)
TyG index	8.94	0.653 (0.579 - 0.728)	66.67 (52.52 - 78.91)	61.55 (57.93 - 65.08)	11.29 (9.86 - 19.22)	96.18 (93.30 - 96-70)	1.73 (1.41 - 2.14)	0.54 (0.37 - 0.79)
TyG-BMI index	226.2	0.680 (0.615 - 0.745)	85.18 (72.88 - 93.38)	46.87 (43.33 - 50.55)	10.53 (9.21 - 22.39)	97.77 (95.27 - 98.04)	1.60 (1.41 - 1.83)	0.32 (0.17 - 0.60)
TyG-WC index	762.56	0.712 (0.650 - 0.775)	90.74 (79.70 - 96.92)	45.24 (41.61 - 48.92)	10.84 (9.49 - 28.11)	98.52 (96.29 - 98.72)	1.66 (1.49 - 1.84)	0.20 (0.09 - 0.47)
Hypertension								
Triglycerides/HDL-C ratio	3.89	0.652 (0.545 - 0.758)	77.27 (54.62 - 92.18)	55.96 (52.41 - 59.46)	4.67 (4.07 - 14.51)	98.87 (96.89 - 99.03)	1.75 (1.38 - 2.23)	0.41 (0.18 - 0.88)
Cholesterol/HDL-C ratio	4.88	0.651 (0.550 - 0.752)	81.82 (59.72 - 94.81)	52.66 (49.11 - 56.20)	4.60 (4.01 - 16.39)	99.04 (97.16 - 99.17)	1.73 (1.40 - 2.13)	0.34 (0.14 - 0.83)
LDL/HDL-C ratio	3.39	0.646 (0.547 - 0.744)	68.18 (45.23 - 86.14)	63.71 (60.24 - 67.07)	4.98 (4.33 - 13.20)	98.62 (96.49 - 98.81)	1.88 (1.39 - 2.54)	0.40 (0.27 - 0.92)
Visceral adiposity index	2.32	0.663 (0.560 - 0.766)	72.73 (49.77 - 89.27)	59.52 (55.99 - 62.97)	4.78 (4.16 - 13.53)	98.74 (96.67 - 98.91)	1.90 (1.37 - 2.35)	0.46 (0.23 - 0.91)
Lipid accumulation product	47.82	0.743 (0.659 - 0.826)	81.81 (59.72 - 94.81)	60.41 (56.89 - 63.84)	5.45 (4.75 - 18.99)	99.17 (97.51 - 99.27)	2.07 (1.67 - 2.56)	0.30 (0.12 - 0.73)
TyG index	8.83	0.703 (0.600 - 0.806)	81.81 (59.72 - 95.81)	54.44 (50.90 - 57.96)	4.77 (4.17 - 16.92)	99.07 (97.25 - 99.20)	1.80 (1.45 - 2.22)	0.33 (0.14 - 0.81)
TyG-BMI index	263.07	0.755 (0.659 - 0.851)	68.18 (45.12 - 86.35)	71.70 (88.41 - 74.82)	6.30 (5.44 - 16.32)	98.78 (96.87 - 98.85)	2.41 (1.77 - 3.27)	0.44 (0.24 - 0.82)
TyG-WC index	862.57	0.801 (0.718 - 0.883)	81.81 (59.72 - 94.81)	70.18 (66.84 - 73.35)	7.11 (6.16 - 23.73)	99.28 (97.85 - 99-38)	2.74 (2.19 - 3.43)	0.25 (0.11 - 0.63)

Se: sensibility; Sp: specificity; PPV: positive predictive value; NPV: negative predictive value; LR+: likelihood ratio positive; LR-: likelihood ratio negative; HDL-C: high-density lipoprotein cholesterol; LDL: low-density lipoprotein; TyG: triglyceride-glucose; TyG-WC: TyG-waist circumference; TyG-BMI: TyG-body mass index; AUC: area under the curve.

nervous system; this leads to an increase in blood pressure. Risk factors like insulin resistance and obesity could disrupt the balance and function of the RAAS, contributing to the development of HTN [38-40].

In addition, WC is a crucial indicator of body fat distribution, specifically visceral fat, which has been associated with a higher risk of HTN. The accumulation of visceral fat in the abdominal area could increase the release of free fatty acids and proinflammatory cytokines, contributing to endothelial dysfunction, insulin resistance, and activation of the RAAS [41]. Epidemiological studies have observed that WC is a better indicator of HTN and CVDs compared to the BMI [42, 43].

Strengths and limitations of the study

The main strength of this manuscript was that it used a nationally representative sample, which lends confidence to the results. Despite this, there were several limitations: the study design is cross-sectional, so causality cannot be determined, and it cannot be extrapolated to other age groups such as children and/or the elderly, as the participants are adults aged between 18 to 59 years.

Conclusions

The TyG-WC is the best diagnostic tool for prehypertension and HTN, hence, it is necessary to conduct prospective research to verify these findings. If confirmed, the TyG-WC can be used as a marker for the prognosis of these two conditions and, thus, to make decisions about prevention.

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The study is self-financed.

Conflict of Interest

The authors declare no conflict of interest.

Informed Consent

To ensure respondent confidentiality, the database was encrypted, preventing the disclosure of participants' full names. Given these precautions and the fact that our study was based

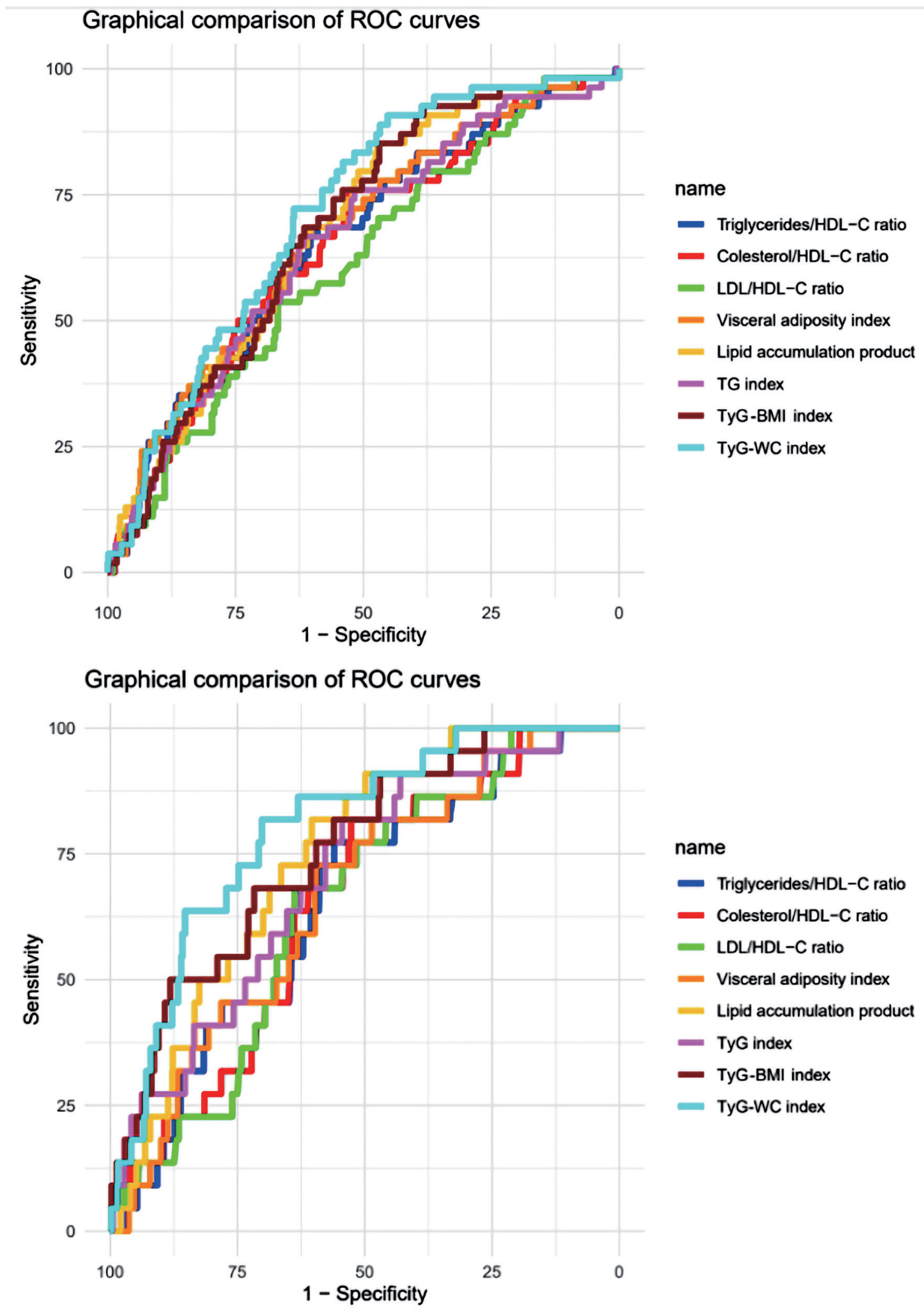

Figure 1. The eight anthropometric indicators are represented by receiver-operating characteristic (ROC) curves. Sensitivity refers to the accurate identification of true positives, while 1-specificity denotes the occurrence of false positives. (a) The panel illustrates the curves for prehypertension. (b) The panel displays the curves for hypertension. HDL-C: high-density lipoprotein cholesterol; LDL: low-density lipoprotein; WC: waist circumference; BMI: body mass index; TyG: triglyceride-glucose.

on a secondary analysis of open-access data, obtaining informed consent was deemed unnecessary.

Author Contributions

Victor Juan Vera-Ponce: conceptualization, data analysis, writing - review and editing. Andrea P. Ramirez-Ortega: investigation, resource acquisition, methodology, writing - original draft. Joan A. Loayza-Castro: data analysis, methodology, validation, writing - original draft. Fiorella E. Zuzunaga-Montoya: data curation, data analysis, methodology, validation, writing - original draft. Jenny Raquel Torres-Malca: validation, visualization, writing - review and editing. Cori Raquel Iturregui

Paucar: supervision, project administration, writing - review and editing. Rosa A. Garcia-Lara: project administration, funding acquisition, writing - review and editing. Jhony A. De La Cruz-Vargas: supervision, writing - review and editing.

Data Availability

The data supporting the findings of this study are open access and can be accessed at "Plataforma Nacional de Datos Abiertos".

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