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Original Article

Association between waist circumference and waist-to-height ratio with insulin resistance biomarkers in normal-weight adults working in a private educational institution

Diego Urrunaga-Pastor, Luciana De La Fuente-Carmelino, Carlos J. Toro-Huamanchumo, Miriam Pérez-Zavala, Vicente A. Benites-Zapata*

Unidad de Investigación para la Generación y Síntesis de Evidencias en Salud, Universidad San Ignacio de Loyola, Lima, Peru

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ABSTRACT

Aim: To assess the association between elevated waist circumference (WC) and high waist-to-height ratio (WHtR) with insulin resistance biomarkers.

Methods: We conducted an analytical cross-sectional study in normal-weight adults. Participants were divided in two groups according to WC or WHtR levels. We considered values of WC $\geq$ 90 in male participants and WC $\geq$ 80 in adult women as elevated, and values of WHtR$\geq$0.50 as high, for both genders. Our outcomes were high triglycerides to HDL-cholesterol (TG/HDL-C) ratio and elevated triglycerides and glucose index (TGI). We considered values of TG/HDL-C ratio $\geq$ 3 as high and TGI values $\geq$ 8.37 as elevated. We elaborated crude and adjusted Poisson generalized linear models to evaluate the proposed associations and explored the gender interaction using stratified models. We reported the prevalence ratio (PR) with their respective 95% confidence intervals (95%CI).

Results: We analyzed 355 participants. The prevalence of elevated WC and high WHtR was 17.2% (n = 61) and 33.2% (n = 118), respectively, while the prevalence of high TG/HDL-C ratio and elevated TGI was 24.8% (n = 88) and 12.7% (n = 45), respectively. In the adjusted regression model, elevated WC was associated with high TG/HDL-C ratio only in female participants (aPR = 3.61; 95%CI: 1.59–8.20). Similarly, high WHtR was associated with high TG/HDL-C ratio in women (aPR = 2.54; 95%CI:1.08–5.97). We found an association with statistically marginal significance between elevated WC and elevated TGI in women (aPR = 1.54; 95%CI: 0.95–2.50); as well as for the association between high WHtR and elevated TGI in male participants (aPR = 1.87; 95%CI: 1.00–3.50).

Conclusion: Elevated WC and high WHtR were associated with a high TG/HDL-C ratio in women. It is necessary to perform prospective follow-up studies in the Peruvian population in order to corroborate our results.

1. Introduction

Insulin resistance (IR) plays a key role in the pathophysiology of metabolic syndrome (MetS) and type 2 diabetes mellitus (T2DM) [1,2]. In addition, it is strongly linked with other non-communicable diseases (NCDs), including cardiovascular abnormalities [3–5] and cancer [6–8]. Therefore, early detection is mandatory, and it should be done even in the absence of symptoms in at-risk populations.

Since the Homeostatic Model Assessment (HOMA-IR) [9] is both expensive and time-consuming [9,10], recent studies have tried to develop and assess surrogate markers for IR [11]. Two of these biomarkers are the triglycerides to HDL-cholesterol (TG/HDL-C) ratio [12–17] and the triglycerides and glucose index (TGI) [15–23]. Both have been tested in different populations with favorable results, even in normal-weight adults [13,14,18,20].

On the other hand, anthropometric indices have been widely used in different studies to assess their relationship with cardiometabolic risk factors [24–27] and IR [28–32]. However, only two of them have been conducted in normal-weight individuals [31,32], which are not uncommon to present metabolic disorders, such as MetS or IR [31,33,34]. Following this, waist circumference

* Corresponding author. Vicerrectorado de Investigación, Universidad San Ignacio de Loyola, Av. la Fontana 750, Lima, 15024, Peru.
E-mail address: vbeniteszapata@gmail.com (V.A. Benites-Zapata).

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(WC) and waist-to-height ratio (WHtR) have shown to be two of the best anthropometric indices to explain some cardiometabolic risk conditions [35–39], although its performance for diagnosis of IR in adults with normal body mass index (BMI) still remains unassessed.

This study aimed to evaluate whether the elevated WC and high WHtR were associated with IR biomarkers in a sample of normal-weight adults.

2. Methods

2.1. Study design and population

We carried out an analytical cross-sectional study in adults with a normal BMI (18.50–24.99 kg/m^2) and no medical history of T2DM, who worked in a private educational institution located in Lima-Peru.

2.2. Sample type and analysis unit

Non-Probabilistic sampling was performed. The sample consisted of all the workers who attended the annual health check-up between January and February 2018 and met the eligibility criteria of the study.

2.3. Procedures

We reviewed all the medical records of the patients evaluated during the annual health check-up and collected all the data of interest. All participants had a minimum fasting period of 8 h for laboratory tests, according to the protocols established by the medical centre. Anthropometric measurements were performed by nurses trained according to the protocols of the World Health Organization (WHO).

2.4. Eligibility criteria

We included adults aged ≥18 with a BMI between 18.50 and 24.99 kg/m^2 and no medical background of T2DM. In addition, we excluded adults aged ≥ 60 and participants with fasting glucose values ≥ 126 mg/dL [40].

2.5. Variables definition

2.5.1. Exposures: WC and WHtR

WC (in centimetres) was categorized in two groups according to sex: normal WC (WC < 90 in male participants and WC < 80 in female adults) and elevated WC (WC ≥ 90 in male participants and WC ≥ 80 in female adults) [41].

WHtR was defined using the following calculation: waist circumference (in centimetres)/height (in centimetres). In addition, participants were divided in two groups: normal WHtR (WHtR values < 0.50) and high WHtR (WHtR values ≥ 0.50) [41].

2.5.2. Outcomes: TG/HDL-C ratio and TGI

We defined the TG/HDL-C ratio using the following calculation: TG (mg/dL)/HDL-C (mg/dL). Then, participants were categorized in two groups: normal TG/HDL-C ratio (TG/HDL-C ratio <3) and high TG/HDL-C ratio (TG/HDL-C ratio ≥3) [12].

We defined the TGI using the following calculation: ln[triglycerides (mg/dL) x fasting glucose (mg/dL)/2]. Then, participants were categorized in two groups according to the 75-percentile value of the TGI: normal TGI levels (TGI values < 8.37) and elevated TGI levels (TGI values ≥ 8.37), as described in previous articles [20,42].

2.5.3. Other variables

The following variables were also included in the analysis: age (years), sex, BMI (kg/m^2), systolic blood pressure (SBP), diastolic blood pressure (DBP), weight, height, fasting glucose, triglycerides, and high-density lipoprotein cholesterol (HDL-C).

2.6. Statistical analysis

We used STATA v14.0 (StataCorp, TX, USA) for our analysis. Descriptive results for numeric variables were presented as means with standard deviation (SD) or medians with interquartile range (IQR), depending on their distributions; otherwise, we expressed the qualitative variables as numbers with percentages. The study population characteristics according to the WC, WHtR, TGI or TG/HDL-C levels were compared using the student t-test or the Wilcoxon rank sum test as appropriate for continuous variables and using the Chi-square test for categorical variables.

Crude and adjusted generalized linear models (all sample and stratified by gender) from Poisson family with robust standard errors were constructed to evaluate the association between elevated WC or high WHtR levels and high TG/HDL-C ratio or elevated TGI. The reported association measure was the prevalence ratio (PR) with their respective 95% confidence intervals (95%CI). The adjusted model included the following confounding variables: age (years) and sex; and the reported association measure was the adjusted prevalence ratio (aPR) with their respective 95%CI.

2.7. Ethical considerations

The data was collected by two researchers from the occupational health department to epidemiological surveillance. For this study, participant information was delivered in a Microsoft Excel 2010 spreadsheet without biological identifiers, maintaining the confidentiality of the data.

3. Results

In total, we enrolled 1095 patients during the study period. We excluded 725 participants because their BMI was not between 18.50 and 24.99 kg/m^2, 2 were withdrawn due to T2DM and 13 because they were 60 or older. Finally, 355 participants were analyzed.

3.1. Characteristics of the study population

The mean age of the participants was 33.5 ± 9.1 (SD) years, 109 (30.7%) were males and the BMI mean was 22.6 ± 1.5 (SD) kg/m^2. The prevalence of elevated WC and high WHtR was 17.2% (n = 61) and 33.2% (n = 118), respectively, while the prevalence of high TG/HDL-C ratio and elevated TGI was 24.8% (n = 88) and 12.7% (n = 45), respectively (Table 1).

3.2. Characteristics of the study population by WC groups

We found higher means of age (37.1 vs. 32.7; p < 0.001), BMI (23.8 vs. 22.4; p < 0.001), weight (61.5 vs. 59.1; p = 0.028), WC (83.6 vs. 77.0; p < 0.001) and WHtR (0.52 vs. 0.47; p < 0.001) in participants with elevated WC levels compared with the normal WC levels group. Additionally, we found a higher median of triglycerides (96 vs. 90; p = 0.044) and TGI mean (8.2 vs. 8.1; p = 0.024) in patients with elevated WC levels compared with the normal WC levels group (Table 1).

Table 1
Characteristics of the study population by WC groups (N = 355).

Variables	N = 355	Normal WC (n = 294)	Elevated WC (n = 61)	P value
Age (years)	33.5 ± 9.1	32.7 ± 9.0	37.1 ± 9.2	<0.001
Male	109 (30.7)	104 (35.4)	5 (8.2)	<0.001
BMI (kg/m^2)	22.6 ± 1.5	22.4 ± 1.5	23.8 ± 1.0	<0.001
SBP (mmHg)	108.2 ± 11.4	108.5 ± 11.6	106.4 ± 10.7	0.185
DBP (mmHg)	65.3 ± 8.3	65.5 ± 8.5	64.2 ± 7.1	0.250
Weight (kg)	59.6 ± 7.8	59.1 ± 8.0	61.5 ± 6.2	0.028
Height (cm)	162.1 ± 8.5	162.4 ± 8.7	160.7 ± 7.2	0.178
WC (cm)	78.2 ± 6.7	77.0 ± 6.6	83.6 ± 4.6	<0.001
WHtR	0.48 ± 0.03	0.47 ± 0.03	0.52 ± 0.02	<0.001
Fasting glucose (mg/dL)	77.0 ± 7.6	77.0 ± 7.5	77.3 ± 8.0	0.720
Triglycerides (mg/dL)	90 (83–112)	90 (82–107)	96 (85–119)	0.044
HDL-C (mg/dL)	50.7 ± 11.7	50.7 ± 11.6	50.8 ± 12.3	0.922
TG/HDL-C ratio	1.9 (1.5–2.4)	1.9 (1.5–2.3)	2.0 (1.6–2.9)	0.132
TGI	8.2 (8.0–8.4)	8.1 (8.0–8.3)	8.2 (8.1–8.5)	0.024

Data expressed as mean ± standard deviation, median (interquartile range) or number (percentage).

3.3. Characteristics of the study population by WHtR groups

Age (37.1 vs. 31.6; p < 0.001), BMI (23.6 vs. 22.1; p < 0.001), weight (61.2 vs. 58.7; p = 0.004), WC (83.7 vs. 75.4; p < 0.001), WHtR (0.52 vs. 0.46; p < 0.001) and fasting glucose (78.3 vs. 76.4; p = 0.026) means were greater in the high WHtR values group compared with the normal WHtR levels group. Moreover, we observed higher medians of triglycerides (96 vs. 88; p = 0.004), TG/HDL-C ratio (2.0 vs. 1.8; p = 0.004) and TGI (8.2 vs. 8.1; p < 0.001) in participants with elevated WHtR levels compared with the normal WHtR levels group (Table 2).

3.4. Characteristics of the study population by TG/HDL-C ratio groups

The prevalence of high TG/HDL-C ratio in the normal WC values group was 11.2% (n = 33), while in participants with elevated WC values were 19.7% (n = 12). In addition, the prevalence of high TG/HDL-C ratio in participants with normal WHtR values was 8.4% (n = 20), whereas in the high WHtR group was 21.2% (n = 25). Moreover, we found a positive correlation between the WC values and the logarithmic TG/HDL-C ratio (r = 0.30; p < 0.001). We also found that WHtR levels correlated positively with TG/HDL-c (r = 0.21; p < 0.001). We found higher means of age (37.0 vs. 33.0; p = 0.006), BMI (23.1 vs. 22.5; p = 0.030), SBP (113.0 vs. 107.5; p = 0.002), DBP (67.8 vs. 64.9; p = 0.027), weight (63.0 vs. 59.1; p = 0.001), height (165.1 vs. 161.6; p = 0.010), WC (82.6 vs. 77.5; p < 0.001) and WHtR (0.50 vs. 0.48; p < 0.001) in participants with high TG/HDL-C ratio compared with the normal TG/HDL-C ratio group (Table 3).

3.5. Characteristics of the study population by TGI ratio groups

The prevalence of elevated TGI ratio in the normal WC values group was 22.8% (n = 67), while in participants with elevated WC values were 34.4% (n = 21). In addition, the prevalence of elevated TGI ratio in participants with normal WHtR values was 20.3% (n = 48), whereas in the high WHtR group was 33.9% (n = 40). Furthermore, we found a positive correlation between the WC and the TGI values (r = 0.27; p < 0.001). We also found that WHtR levels correlated positively with TGI values (r = 0.22; p < 0.001). We found higher means of age (36.4 vs. 32.5; p < 0.001), SBP (111.0 vs. 107.2; p = 0.006), DBP (68.0 vs. 64.4; p < 0.001), weight (61.7 vs. 58.9; p = 0.003), height (164.1 vs. 161.4; p = 0.010), WC (80.9 vs. 77.3; p < 0.001) and WHtR (0.49 vs. 0.48; p < 0.001), fasting glucose (80.2 vs. 76.0; p < 0.001) in participants with elevated TGI compared with the normal TGI levels group (Table 4).

3.6. Generalized linear models from Poisson family to assess the association between elevated WC or high WHtR and high TG/HDL-C ratio

In the crude Poisson regression model to calculate the association between elevated WC and high TG/HDL-C ratio, compared with the normal WC group, we found no statistically significant association between elevated WC and TG/HDL-C ratio in all sample

Table 2
Characteristics of the study population by WHtR groups (N = 355).

Variables	Normal WHtR (n = 237)	High WHtR (n = 118)	P value
Age (years)	31.6 ± 8.3	37.1 ± 9.6	<0.001
Male	63 (26.6)	46 (39.0)	0.017
BMI (kg/m^2)	22.1 ± 1.5	23.6 ± 1.1	<0.001
SBP (mmHg)	107.9 ± 11.4	108 ± 11.4	0.482
DBP (mmHg)	65.2 ± 8.2	65.5 ± 8.5	0.784
Weight (kg)	58.7 ± 7.9	61.2 ± 7.1	0.004
Height (cm)	162.7 ± 8.4	160.9 ± 8.5	0.058
WC (cm)	75.4 ± 5.6	83.7 ± 5.2	<0.001
WHtR	0.46 ± 0.02	0.52 ± 0.02	<0.001
Fasting glucose (mg/dL)	76.4 ± 7.3	78.3 ± 8.1	0.026
Triglycerides (mg/dL)	88 (82–102)	96 (83–125)	0.004
HDL-C (mg/dL)	51.2 ± 11.6	49.8 ± 11.9	0.301
TG/HDL-C ratio	1.8 (1.5–2.3)	2.0 (1.6–2.9)	0.004
TGI	8.1 (8.0–8.3)	8.2 (8.1–8.6)	<0.001

Data expressed as mean ± standard deviation, median (interquartile range) or number (percentage).

Table 3
Characteristics of the study population based on TG/HDL-C ratio groups (N = 355).

Variables	Normal TG/HDL-C ratio (n = 310)	High TG/HDL-C ratio (n = 45)	P value
Elevated WC	49 (80.3)	12 (19.7)	0.071
High WHtR	93 (78.8)	25 (21.2)	0.001
Age (years)	33.0 ± 8.9	37.0 ± 10.2	0.006
Male	85 (78.0)	24 (22.0)	<0.001
BMI (kg/m^2)	22.5 ± 1.6	23.1 ± 1.3	0.030
SBP (mmHg)	107.5 ± 11.0	113.0 ± 13.1	0.002
DBP (mmHg)	64.9 ± 8.0	67.8 ± 9.3	0.027
Weight (kg)	59.1 ± 7.6	63.0 ± 7.6	0.001
Height (cm)	161.6 ± 8.3	165.1 ± 9.3	0.010
WC (cm)	77.5 ± 6.6	82.6 ± 5.9	<0.001
WHtR	0.48 ± 0.03	0.50 ± 0.02	<0.001
Fasting glucose (mg/dL)	76.9 ± 7.4	77.9 ± 8.8	0.403
Triglycerides (mg/dL)	88 (81–99)	167 (150–202)	<0.001
HDL-C (mg/dL)	52.1 ± 11.2	41.4 ± 11.1	<0.001
TG/HDL-C ratio	1.8 (1.5–2.2)	4.0 (3.5–5.1)	<0.001
TGI	8.1 (8.0–8.3)	8.8 (8.6–9.0)	<0.001

Data expressed as mean ± standard deviation, median (interquartile range) or number (percentage).

Table 4
Characteristics of the study population based on TGI groups (N = 355).

Variables	Normal TGI (n = 267)	Elevated TGI (n = 88)	P value
Elevated WC	40 (65.6)	21 (34.4)	0.055
High WHtR	78 (66.1)	40 (33.9)	0.005
Age (years)	32.5 ± 8.8	36.4 ± 9.6	<0.001
Male	76 (69.7)	33 (30.3)	0.111
BMI (kg/m^2)	22.5 ± 1.5	22.8 ± 1.5	0.096
SBP (mmHg)	107.2 ± 11.2	111.0 ± 11.7	0.006
DBP (mmHg)	64.4 ± 8.0	68.0 ± 8.6	<0.001
Weight (kg)	58.9 ± 7.7	61.7 ± 7.6	0.003
Height (cm)	161.4 ± 8.5	164.1 ± 8.3	0.010
WC (cm)	77.3 ± 6.4	80.9 ± 7.0	<0.001
WHtR	0.5 ± 0.03	0.5 ± 0.03	<0.001
Fasting glucose (mg/dL)	76.0 ± 7.0	80.2 ± 8.5	<0.001
Triglycerides (mg/dL)	86 (80–93)	150 (121–173)	<0.001
HDL-C (mg/dL)	51.1 ± 11.2	49.6 ± 13.2	0.318
TG/HDL-C ratio	1.7 (1.4–2.1)	3.0 (2.3–4.0)	<0.001
TGI	8.1 (8.0–8.2)	8.6 (8.5–8.9)	<0.001

Data expressed as mean ± standard deviation, median (interquartile range) or number (percentage).

(PR = 1.75; 95%CI: 0.96–3.20). However, in the crude stratified analysis by gender, elevated WC was associated with a higher prevalence of high TG/HDL-C ratio in female participants (PR = 3.73; 95%CI: 1.67–8.34). In the adjusted model for the entire sample, the association was statistically significant (aPR = 2.25; 95% CI: 1.20–4.25) but in the stratified analysis by gender, only in female participants the association remained statistically significant (aPR = 3.61; 95%CI: 1.59–8.20) (Table 5).

In the crude Poisson regression model to calculate the association between high WHtR and high TG/HDL-C ratio, compared with the normal WHtR group, we found statistically significant association between high WHtR and high TG/HDL-C ratio in all the sample (PR = 2.51; 95%CI: 1.45–4.33) and in female participants (PR = 2.66; 95%CI: 1.18–6.00). Similarly, in the adjusted model, we showed that the association remained statistically significant for the entire sample (aPR = 1.91; 95%CI: 1.06–3.43) and in female participants (aPR = 2.54; 95%CI: 1.08–5.97) (Table 5).

Table 5
Generalized linear models from Poisson family with robust standard errors to assess the association between elevated WC or high WHtR and high TG/HDL-C ratio.

Exposure variable	Population	Exposure group	Crude PR (95% CI)	P value	Adjusted PR (95% CI)	P value
WC	All sample	Normal	Reference	–	Reference	–
		Elevated	1.75 (0.96–3.20)	0.067	2.25 (1.20–4.25)[a]	0.012
WC	Female	Normal	Reference	–	Reference	–
		Elevated	3.73 (1.67–8.34)	0.001	3.61 (1.59–8.20)[b]	0.002
WC	Male	Normal	Reference	–	Reference	–
		Elevated	0.90 (0.15–5.46)	0.913	0.56 (0.14–2.23)[b]	0.413
WHtR	All sample	Normal	Reference	–	Reference	–
		Elevated	2.51 (1.45–4.33)	0.001	1.91 (1.06–3.43)[a]	0.030
WHtR	Female	Normal	Reference	–	Reference	–
		Elevated	2.66 (1.18–6.00)	0.018	2.54 (1.08–5.97)[b]	0.032
WHtR	Male	Normal	Reference	–	Reference	–
		Elevated	1.92 (0.93–3.94)	0.077	1.46 (0.67–3.15)[b]	0.340

[a] Adjusted by: age (years) and sex.
[b] Adjusted by age (years).

3.7. Generalized linear models from Poisson family to assess the association between elevated WC or high WHtR and elevated TGI

In the crude Poisson regression model to calculate the association between elevated WC and elevated TGI, compared with the normal WC group, we found statistically significant association between elevated WC and elevated TGI in all the sample (PR = 1.51; 95%CI: 1.01–2.27) and in female participants (PR = 1.65; 95%CI: 1.02–2.66). However, in the adjusted model, the association showed marginal statistical significance for the entire sample and in the female participants (aPR = 1.49; 95%CI: 0.97–2.29) and (aPR = 1.54; 95%CI: 0.95–2.50); respectively (Table 6).

In the crude Poisson regression model to calculate the association between high WHtR and elevated TGI, compared with the normal WHtR group, we found a higher prevalence of elevated TGI evaluating all sample (PR = 1.67; 95%CI: 1.17–2.39) and in male participants (PR = 2.40; 95%CI: 1.31–4.37). Nevertheless, in the adjusted model, the association showed marginal statistical significance for the entire sample and in the male participants (aPR = 1.39; 95%CI: 0.96–2.00) and (aPR = 1.87; 95%CI: 1.00–2.50), respectively (Table 6).

4. Discussion

4.1. Main findings

In this cross-sectional study, we assessed the relationship between WC and WHtR with two biomarkers of IR in a sample of normal-weight adults. Overall, elevated WC and WHtR were associated with a high TG/HDL-C ratio only in women. Although none of the anthropometric indices showed statistically significant differences with TGI, we found marginal statistical significance in the association between elevated WC and elevated TGI for female participants. Similarly, we found marginal statistical significance in the association between high WHtR and elevated TGI for male participants.

4.2. Comparison with other studies

We only found one study that described the association between high WHtR and high TG/HDL-C ratio in all of the age and gender groups [43]. In addition, similar studies have reported that both WC [44–48] and WHtR [47,48] are positively correlated with TG/HDL-C. However, these results were positive for both sexes, whereas in our study we only found an association in the female group.

We did not find literature that assessed the relationship between the two anthropometric indices used in the study with TGI. Moreover, we have found a trend toward a higher prevalence of elevated TGI in female participants with elevated WC, as well as a higher prevalence of elevated TGI in male participants with high WHtR. Our findings suggest an effect modification or interaction between the genre and the proposed outcomes. We show a higher prevalence of the proposed outcomes in women. However, our findings should be interpreted with caution, so other studies can evaluate the consistency of our findings are necessary.

4.3. Results interpretation

Current literature evidence that WC and WHtR are suitable proxy measures for central obesity [49,50] and visceral adipose tissue (VAT) [51,52], respectively. Central obesity has been linked with hypertriglyceridemia, and recent studies have proposed a dual mechanism for this association: i) increased triglyceride-rich lipoprotein secretion and ii) impairment of clearance of these lipoproteins [53,54]. Furthermore, this process also involves the abnormal secretion of very-low-density lipoproteins (VDLs) which is associated with increased visceral adiposity [53,55]. Similarly, VAT is strongly associated with an abnormal lipid profile. This could be understood by the fact that VAT exhibits a high spontaneous lipolysis activity which promotes the release of free fatty acids (FFAs) to the circulation [56–58].

On the other hand, we found that WC and WHtR were associated with TG/HDL-C only in women. Middle-aged men usually have higher triglycerides and lower HDL-C than women of a similar age [59]. Similarly, men generally have greater visceral fat and are more prone to central obesity than women [51,59]. Thus, an alteration -even minimal in any of these factors could represent a more severe risk for women than for men, especially in postmenopausal women [60–63]. In addition, there is evidence that in centrally obese women, WHtR is positively correlated with several inflammatory markers (i.e. C-reactive protein, interleukin (IL-) 6 and IL-10) [64], which could also be related with a greater risk for atherosclerotic vascular disease in these population.

4.4. Relevance and implications

IR is a complex metabolic condition strongly linked with T2DM, MetS, cardiovascular abnormalities and other NCDs [1–7]. The gold standard for IR is the HOMA-IR, however, it has some limitations mainly related to cost and accessibility [9,10]. For this reason, different studies have been carried out in recent years in order to test surrogate markers for IR, such as TG/HDL-C ratio [12–17] and TGI [15–21,28,65]. Similarly, some anthropometric indices have

Table 6
Generalized linear models from Poisson family with robust standard errors to assess the association between elevated WC or high WHtR and elevated TGI.

Exposure variable	Population	Exposure group	Crude PR (95% CI)	P value	Adjusted PR (95% CI)[a]	P value
WC	All sample	Normal	Reference	–	Reference	–
		Elevated	1.51 (1.01–2.27)	0.046	1.49 (0.97–2.29)[a]	0.069
WC	Female	Normal	Reference	–	Reference	–
		Elevated	1.65 (1.02–2.66)	0.040	1.54 (0.95–2.50)[b]	0.082
WC	Male	Normal	Reference	–	Reference	–
		Elevated	2.08 (0.95–4.54)	0.066	1.36 (0.54–3.40)[b]	0.513
WHtR	All sample	Normal	Reference	–	Reference	–
		Elevated	1.67 (1.17–2.39)	0.005	1.39 (0.96–2.00)[a]	0.080
WHtR	Female	Normal	Reference	–	Reference	–
		Elevated	1.28 (0.79–2.07)	0.325	1.15 (0.70–1.89)[b]	0.575
WHtR	Male	Normal	Reference	–	Reference	–
		Elevated	2.40 (1.31–4.37)	0.004	1.87 (1.00–3.50)[b]	0.051

[a] Adjusted by: age (years) and sex.
[b] Adjusted by age (years).

shown to be very useful for predicting several cardiometabolic risk factors [24–27], and different studies report that WC and WHtR are two of the indices that have a better performance [35–38,66].

Nowadays, we need accessible and easy-to-measure tools for early and accurate diagnosis of metabolic abnormalities, not only in at-risk populations but also in normal-weight healthy subjects. In this sense, lipid profile and glucose are low-cost biochemical tests that are usually requested in routine clinical practice [13,20]. Similarly, WC and WHtR are easy-to-measure indices and they both are less prone to measurement and calculation errors [36,39,67].

4.5. Limitations

Some limitations must be highlighted. First, we did not assess causality due to the cross-sectional nature of our study. Second, we used information collected from medical records, which may have had some filling errors; nevertheless, we conducted a rigorous evaluation of the data quality to reduce the possibility of information bias. Third, our study was conducted in a single educational institution, thus we cannot generalize our results to the Peruvian population and further studies should be conducted.

5. Conclusions

We found that WC and WHtR were associated with a high TG/HDL-C ratio in women, but none of them was associated with TGI. We recommend carrying out prospective follow-up studies in the Peruvian population in order to corroborate these results. In addition, novel anthropometric indices should be assessed.

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Conflicts of interest

All authors declare having no conflicts of interest regarding this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dsx.2019.04.039.

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