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Original Article

High triglycerides to HDL-cholesterol ratio is associated with insulin resistance in normal-weight healthy adults

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ABSTRACT

Aim: To evaluate the association between high triglyceride/HDL-cholesterol (TG/HDL-C) ratio and insulin resistance (IR) or hyperinsulinemia after oral glucose tolerance test (OGTT) in normal-weight healthy adults.

Methods: We carried out an analytical cross-sectional study in euthyroid non-diabetic adults, who attended the outpatient service of a private clinic in Lima-Peru from 2012 to 2016. Participants were divided in two groups according to the presence or absence of high TG/HDL-C ratio, IR or hyperinsulinemia after OGTT. TG/HDL-C ratio values ≥ 3 were considered as high. IR was defined as a Homeostasis Model Assessment (HOMA-IR) value ≥ 2.28 and hyperinsulinemia after OGTT as a serum insulin value $\geq 80\mu U/mL$ after 120 min of 75-g glucose intake. We elaborated crude and adjusted Poisson generalized linear models to evaluate the association between high TG/HDL-C ratio and IR or hyperinsulinemia after OGTT and reported the prevalence ratio (PR) with their respective 95% confidence intervals (95%CI).

Results: We analyzed the data of 118 individuals. Prevalence of high TG/HDL-C ratio was 17.8% ($n = 21$) while the prevalence of IR and hyperinsulinemia after OGTT was 24.6% ($n = 29$) and 17.0% ($n = 20$), respectively. TG/HDL-C-ratio values were positively correlated with HOMA-IR ($r = 0.498$; $p < 0.01$) and serum insulin after OGTT ($r = 0.326$; $p < 0.001$). In the adjusted model, high TG/HDL-C ratio was associated with both IR (aPR = 3.16; 95%CI: 1.80–5.77) and hyperinsulinemia after OGTT (aPR = 2.36; 95%CI: 1.20–4.63).

Conclusions: High TG/HDL-C ratio was associated with both IR markers used in our study, appearing to be a clinically useful tool to assess IR in euthyroid normal-weight adults without type 2 diabetes mellitus.

1. Introduction

Insulin resistance (IR) is considered a complex metabolic disorder [1,2] defined as the inability of insulin to properly ensure the glucose uptake and utilization [3]. IR represents an important clinical condition, as it is strongly associated with different types of cancer [4–7] and several cardiovascular [8–10], metabolic [11–13] and brain disorders [14–16].

To date, the hyperinsulinemic-euglycemic clamp remains as the gold standard for IR [17] and HOMA-IR is the most widely used alternative [18,19]. However, both have some limitations, mainly related to cost, accessibility, reproducibility and replicability [17,19–22]. Thus, in recent years, different studies worldwide have tried to develop and assess new markers for IR [23].

It is known that hypertriglyceridemia and low levels of high density lipoprotein cholesterol (HDL-C) play an important role in

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the pathogenesis of IR and metabolic syndrome [24–28]. In addition, current literature mentions that it is not uncommon for people with a normal body mass index (BMI) to present metabolic disorders [29–32]. In this sense, the use of lipid markers could be useful for an early and accurate diagnosis of IR, when the two previously mentioned measures are not available.

In Latin America, two studies conducted in adult populations in Mexico [33] and Argentina [34] aimed to assess the performance of the Triglycerides (TG)/HDL-C ratio for IR diagnosis, showing some favourable results. Peru is a country that has been through a nutritional transition during the last years, with an increase in the prevalence of non-communicable diseases [35]. Nevertheless, few studies have been conducted in order to evaluate the performance of surrogate biomarkers for IR [36,37], and this TG/HDL-C ratio still remains unassessed.

For the above mentioned, the objective of the study was to assess the association between high TG/HDL-C ratio and IR or hyperinsulinemia after oral glucose tolerance test (OGTT) in a sample of normal-weight adults.

2. Methods

2.1. Study design and population

We conducted an analytical cross-sectional study in euthyroid adults of both sexes with a normal BMI and no medical history of type 2 diabetes mellitus (T2DM), who attended the outpatient service of a private clinic in Lima-Peru through 2012–2016.

2.2. Sample type and analysis unit

We performed a non-probabilistic sampling. We included all patients who attended the outpatient service of the private clinic between January 2012 and December 2016 and met the eligibility criteria of the study.

2.3. Procedures

We reviewed all the medical records of the patients treated during the study period and collected all the data of interest. The laboratory values were only collected if the patient laboratory tests were performed with a maximum of 30 days after they were attended in the outpatient service of the private clinic. All participants had a minimum fasting period of eight hours for laboratory tests, according to the protocols established by the medical centre.

2.4. Eligibility criteria

We included participants aged ≥18 with a BMI between 18.50 and 24.99 kg/m^2 and no medical history of T2DM, hypothyroidism, subclinical hypothyroidism, hyperthyroidism, polycystic ovary syndrome or metabolic syndrome. Besides, we excluded patients aged ≥60, with fasting glucose values ≥ 126 mg/dL, OGTT ≥200 mg/dL, thyroid hormones values outside the following ranges: free triiodothyronine (FT3): 2.3–4.2 pg/mL, free thyroxine (FT4): 0.89–1.76 ng/dL, thyroid stimulating hormone (TSH): 0.40–5.0 μU/mL [36]; and pregnant women.

2.5. Variables definition

2.5.1. Exposure: TG/HDL-C ratio

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) [33].

2.5.2. Outcomes: IR and hyperinsulinemia after OGTT

IR was defined as a HOMA-IR value ≥ 2.28, that correlates with the 75-percentile. We used this cut-off point based in a previous study [38]. Mathews et al. (1985) proposed HOMA-IR in a mathematical model to assess hyperinsulinemia. The gold standard to assess IR is the hyperinsulinemic euglycemic clamp, however HOMA-IR is well correlated with it and was calculated using the formula: fasting glucose (mg/dL) x fasting insulin (μU/mL)/405 [18].

Hyperinsulinemia after OGTT was defined as a serum insulin value ≥ 80μU/mL after 120 min of 75-g glucose intake [39]. Participants were divided in two groups according to these criteria.

2.5.3. Other variables

The following variables were also included in the analysis: age (years), sex, BMI, fasting glucose, postprandial blood glucose, glycated haemoglobin A1c, fasting insulin, TG, HDL-C, low-density lipoprotein cholesterol (LDL-C), total cholesterol, FT3, FT4, FT3/FT4 ratio and TSH.

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. Categorical variables were expressed as numbers with percentages. The study population characteristics according to the TG/HDL-C ratio groups, IR or hyperinsulinemia after OGTT were compared using the student T test or the Wilcoxon rank sum test as appropriate for numeric variables and using the Chi-square test for categorical variables. The Pearson correlation coefficient (rho) was used to assess the relationship between numeric variables as TG/HDL-C ratio and HOMA-IR or serum insulin after OGTT values. For correlations, the numeric variables were transformed to a normal distribution using a logarithmic transformation.

Two generalized linear models (1 crude and 1 adjusted) from Poisson family with robust standard errors were constructed to evaluate the association between high TG/HDL-C ratio and IR or hyperinsulinemia after OGTT. 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, sex, FT3/FT4 ratio and TSH (μU/mL) [40,41]; 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 private clinic to study epidemiological surveillance. Participant information was kept confidential and recorded into a Microsoft Excel 2010 file without biological identifiers.

3. Results

We enrolled a total of 1817 patients during the study period; we excluded 222 participants because they were 60 or older. Besides, 625 patients were withdrawn due to hyperthyroidism, hypothyroidism, subclinical hypothyroidism or T2DM, 695 because their BMI was not between 18.50 and 24.99 kg/m^2 and 157 because they did not have the variables of interest. Finally, data of 118 participants was analyzed.

3.1. Characteristics of the study population

The average age of the participants was 37.2 ± 11.3 (SD) years, 21

(17.8%) were males and the mean BMI was 22.7 ± 1.6 (SD) kg/m^2. The prevalence of high TG/HDL-C ratio was 17.8% (n = 21) while the prevalence of IR and hyperinsulinemia after OGTT was 24.6% (n = 29) and 17.0% (n = 20), respectively.

We found a TG median of 84 (IQR: 62–130) mg/dL and an HDL-C mean of 56.5 ± 16.8 (mg/dL). Furthermore, the FT3, FT4, FT3/FT4 ratio and TSH, mean or median values were 3.1 ± 0.4 pg/mL, 1.2 ± 0.2 ng/dL, 2.6 ± 0.4 and 2.3 (IQR: 1.4–3.1) μU/mL, respectively. In addition, the fasting glucose, fasting insulin and HOMA-IR, mean or median values were 86.6 ± 8.1 mg/dL, 7.7 (IQR: 5.1–10.7) (μU/mL) and 1.6 (IQR: 1.1–2.3), respectively. The group with normal TG/HDL-C ratio had a median of 1.3 (IQR: 1.0–1.9), while the high TG/HDL-C ratio group had a median of 4.3 (IQR: 3.4–5.3), with statistically significant differences (Table 1).

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

We observed higher means of BMI (23.5 vs. 22.5; p = 0.014) and fasting glucose (90.0 vs. 85.8; p = 0.031) in participants with high TG/HDL-C ratio compared with the normal TG/HDL-C ratio group. Additionally, we found higher medians of fasting insulin (10.2 vs. 7.3; p < 0.001), serum insulin after OGTT (60.3 vs. 33.9; p = 0.023) and HOMA-IR (2.5 vs. 1.5; p < 0.001) in patients with high TG/HDL-C ratio compared with the group without this condition. Besides, we found a higher TG median (175 vs. 76; p < 0.001) and a lower HDL-C mean (39.7 vs. 60.1; p < 0.001) in participants with high TG/HDL-C ratio compared with the normal TG/HDL-C ratio group (Table 1).

3.3. Characteristics of the study population based on IR

We found higher means of BMI (23.4 vs. 22.5; p = 0.004), fasting glucose (94.0 vs. 84.2; p < 0.001), postprandial glucose (115.4 vs. 85.1; p < 0.001), glycated haemoglobin A1c (5.5 vs. 5.3; p = 0.034), LDL-C (127.4 vs. 106.2; p = 0.010), total cholesterol (208.5 vs. 183.5; p < 0.001) and FT3/FT4 ratio (2.7 vs. 2.5; p = 0.024) in participants with IR compared with the no IR group.

As well, we observed higher medians of fasting insulin (13.2 vs. 6.8; p < 0.001), serum insulin after OGTT (75.1 vs. 29.8; p < 0.001), HOMA-IR (3.1 vs. 1.4; p < 0.001) and triglycerides (135 vs. 75; p < 0.001) in participants with IR compared with the no IR group. In addition, we found a higher triglycerides/HDL-C ratio median (2.8 vs. 1.3; p < 0.001) and a lower FT4 mean (1.2 vs. 1.3; p = 0.013) in participants with IR compared with the no IR group (Table 2).

3.4. Characteristics of the study population based on hyperinsulinemia after OGTT

Equally, we found a higher mean of fasting glucose (93.0 vs. 85.3; p < 0.001), postprandial glucose (126.3 vs. 85.7; p < 0.001), glycated haemoglobin A1c (5.6 vs. 5.3; p = 0.004), LDL-C (128.4 vs. 108.3; p = 0.039) and FT3/FT4 ratio (2.8 vs. 2.5; p < 0.001) in participants with hyperinsulinemia after OGTT compared with the group without this condition. Moreover, we observed higher medians of fasting insulin (12.1 vs. 7.2; p < 0.001), serum insulin after OGTT (112.8 vs. 31.1; p < 0.001), HOMA-IR (3.0 vs. 1.5; p < 0.001), TG (130.5 vs. 77.5; p < 0.001) and TG/HDL-C ratio (2.9 vs. 1.3; p < 0.001) in participants with hyperinsulinemia after OGTT compared with the normal group (Table 3).

3.5. Correlations between the logarithmic values of TG/HDL-C ratio and the logarithmic values of HOMA-IR or serum insulin after OGTT

We found a positive correlation between the logarithmic TG/HDL-C ratio values and the logarithmic HOMA-IR values (r = 0.498; p < 0.01) (Fig. 1). Similarly, we found a positive correlation between the logarithmic TG/HDL-C ratio values and the logarithmic serum insulin after OGTT values (r = 0.326; p < 0.001) (Fig. 2).

3.6. Generalized linear models from Poisson family to assess the association between high TG/HDL-C ratio and IR or hyperinsulinemia after OGTT

In the crude Poisson regression model to calculate the association between high TG/HDL-C ratio and IR, compared with the normal TG/HDL-C ratio group, the prevalence of IR was higher (PR = 3.26; 95% CI: 1.84–5.77). Similarly, the association remained in the adjusted model for age (years), sex, FT3/FT4 and TSH (μU/mL) (aPR = 3.16; 95% CI: 1.80–5.77) (Table 4).

In the crude Poisson regression model to evaluate the association between high TG/HDL-C ratio and hyperinsulinemia after OGTT, compared with the normal TG/HDL-C ratio group, the prevalence of hyperinsulinemia after OGTT was higher (PR = 3.08; 95% CI: 1.44–6.61). Finally, after adjusting for age (years), sex, FT3/FT4 and TSH (μU/mL), the association remained significant (aPR = 2.36; 95% CI: 1.20–4.63) (Table 4).

Table 1
Characteristics of the study population by TG/HDL-C ratio groups (N = 118).

Variables	N = 118	Normal (n = 97)	High (n = 21)	P value
Age (years)	37.2 ± 11.3	36.5 ± 11.4	40.2 ± 10.9	0.181
Male	21 (17.8)	16 (16.5)	5 (23.8)	0.528
BMI (kg/m^2)	22.7 ± 1.6	22.5 ± 1.7	23.5 ± 0.9	0.014
Fasting glucose (mg/dL)	86.6 ± 8.1	85.8 ± 7.0	90.0 ± 11.8	0.031
Postprandial glucose (mg/dL)	92.6 ± 26.5	90.7 ± 25.0	101.3 ± 31.8	0.096
Fasting insulin (μU/mL)	7.7 (5.1–10.7)	7.3 (4.8–10.0)	10.2 (8.4–16.2)	<0.001
Serum insulin after OGTT (μU/mL)	37.5 (22.5–68.4)	33.9 (22.3–62.1)	60.3 (36.8–109.5)	0.023
Glycated haemoglobin A1c (%)	5.4 ± 0.4	5.4 ± 0.3	5.5 ± 0.6	0.183
HOMA-IR	1.6 (1.1–2.3)	1.5 (1.1–2.1)	2.5 (1.6–3.8)	<0.001
Triglycerides (mg/dL)	84 (62–130)	76 (58–97)	175 (140–227)	<0.001
HDL-C (mg/dL)	56.5 ± 16.8	60.1 ± 15.8	39.7 ± 9.7	<0.001
LDL-C (mg/dL)	111.8 ± 36.6	110.9 ± 36.8	115.6 ± 36.2	0.611
Total cholesterol (mg/dL)	189.8 ± 40.9	188.2 ± 41.4	196.6 ± 38.7	0.400
TG/HDL-C ratio	1.5 (1.1–2.62)	1.3 (1.0–1.9)	4.3 (3.4–5.3)	<0.001
FT3 (pg/mL)	3.1 ± 0.4	3.1 ± 0.4	3.1 ± 0.3	0.570
FT4 (ng/dL)	1.2 ± 0.2	1.3 ± 0.2	1.2 ± 0.2	0.033
FT3/FT4 ratio	2.6 ± 0.4	2.5 ± 0.4	2.7 ± 0.4.	0.094
TSH (μU/mL)	2.3 (1.4–3.1)	2.2 (1.4–3.1)	2.4 (1.6–3.6)	0.467

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

Table 2
Characteristics of the study population based on IR (N = 118).

Variables	No IR (n = 89)	IR (n = 29)	P value
High TG/HDL-C ratio	9 (42.9)	12 (57.1)	<0.001
Age (years)	36.5 ± 10.9	39.4 ± 12.5	0.230
Male	20 (95.2)	1 (4.8)	0.020
BMI (kg/m^2)	22.5 ± 1.6	23.4 ± 1.3	0.004
Fasting glucose (mg/dL)	84.2 ± 5.7	94.0 ± 10.0	<0.001
Postprandial glucose (mg/dL)	85.1 ± 20.9	115.4 ± 29.0	<0.001
Fasting insulin (μU/mL)	6.8 (4.8–8.4)	13.2 (11.6–16.7)	<0.001
Serum insulin after OGTT (μU/mL)	29.8 (20.2–45.3)	75.1 (60.3–109.7)	<0.001
Glycated haemoglobin A1c (%)	5.3 ± 0.3	5.5 ± 0.5	0.034
HOMA-IR	1.4 (1.0–1.8)	3.1 (2.5–3.8)	<0.001
Triglycerides (mg/dL)	75 (56–97)	135 (108.5–171)	<0.001
HDL-C (mg/dL)	58.5 ± 17.5	50.1 ± 12.7	0.018
LDL-C (mg/dL)	106.2 ± 33.9	127.4 ± 39.8	0.010
Total cholesterol (mg/dL)	183.5 ± 38.5	208.5 ± 42.6	<0.001
TG/HDL-C ratio	1.3 (0.9–1.9)	2.8 (2.0–3.9)	<0.001
FT3 (pg/mL)	3.1 ± 0.4	3.1 ± 0.4	0.997
FT4 (ng/dL)	1.3 ± 0.2	1.2 ± 0.2	0.013
FT3/FT4 ratio	2.5 ± 0.4	2.7 ± 0.3	0.024
TSH (μU/mL)	2.3 (1.4–3.2)	2.3 (1.6–2.8)	0.864

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

Table 3
Characteristics of the study population based on hyperinsulinemia after OGTT (N = 118).

Variables	No hyperinsulinemia after OGTT (n = 98)	Hyperinsulinemia after OGTT (n = 20)	P value
High TG/HDL-C ratio	13 (61.9)	8 (38.1)	0.009
Age (years)	36.6 ± 11.1	40.3 ± 12.5	0.185
Male	20 (95.2)	2 (4.8)	0.120
BMI (kg/m^2)	22.6 ± 1.6	23.1 ± 1.5	0.283
Fasting glucose (mg/dL)	85.3 ± 6.9	93.0 ± 10.8	<0.001
Postprandial glucose (mg/dL)	85.7 ± 21.3	126.3 ± 23.8	<0.001
Fasting insulin (μU/mL)	7.2 (4.8–9.2)	12.1 (10.1–18.5)	<0.001
Serum insulin after OGTT (μU/mL)	31.1 (21.1–48.3)	112.8 (103.1–134.1)	<0.001
Glycated haemoglobin A1c (%)	5.3 ± 0.3	5.6 ± 0.5	0.004
HOMA-IR	1.5 (1.1–2.0)	3.0 (2.1–4.3)	<0.001
Triglycerides (mg/dL)	77.5 (59–123)	130.5 (103–195)	<0.001
HDL-C (mg/dL)	57.7 ± 17.2	50.6 ± 13.7	0.087
LDL-C (mg/dL)	108.3 ± 33.9	128.4 ± 44.8	0.039
Total cholesterol (mg/dL)	186.8 ± 38.9	203.4 ± 47.6	0.100
TG/HDL-C ratio	1.3 (1.0–2.2)	2.9 (1.9–3.8)	<0.001
FT3 (pg/mL)	3.1 ± 0.4	3.2 ± 0.4	0.574
FT4 (ng/dL)	1.3 ± 0.2	1.1 ± 0.2	0.001
FT3/FT4 ratio	2.5 ± 0.4	2.8 ± 0.4	<0.001
TSH (μU/mL)	2.3 (1.4–3.1)	2.4 (1.8–3.5)	0.360

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

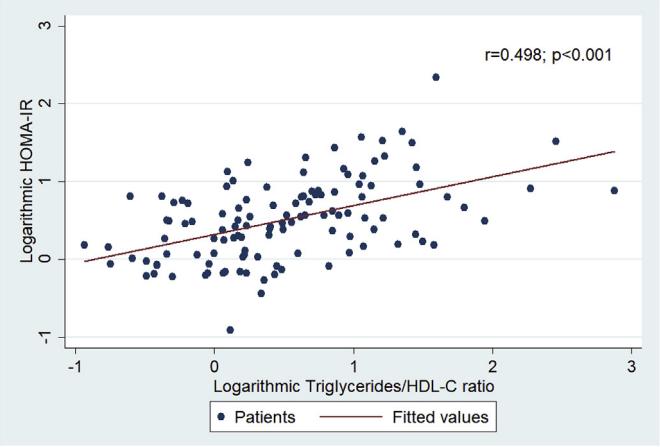

Fig. 1. Scatter plot for the correlation between the logarithmic TG/HDL-C ratio values and the logarithmic HOMA-IR values.

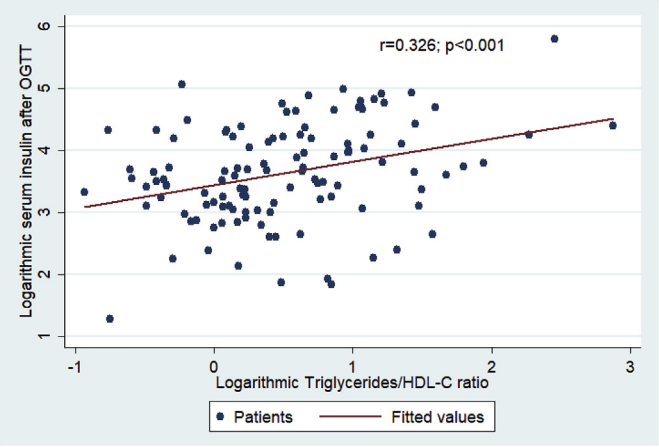

Fig. 2. Scatter plot for the correlation between the logarithmic TG/HDL-C ratio values and the logarithmic serum insulin after OGTT values.

Table 4
Generalized linear models from Poisson family with robust standard errors to assess the association between High TG/HDL-C ratio and IR or Hyperinsulinemia after OGTT.

Outcomes	Variables	Crude PR (95% CI)	P value	Adjusted PR (95% CI)[a]	P value
IR	Normal TG/HDL-C ratio	Reference	–	Reference	–
	High TG/HDL-C ratio	3.26 (1.84–5.77)	<0.001	3.16 (1.80–5.57)	<0.001
Hyperinsulinemia after OGTT	Normal TG/HDL-C ratio	Reference	–	Reference	–
	High TG/HDL-C ratio	3.08 (1.44–6.61)	0.004	2.36 (1.20–4.63)	0.012

[a] Adjusted by: age (years), sex, FT3/FT4 ratio and TSH (μU/mL).

4. Discussion

4.1. Main findings

To our knowledge, only two studies in Latin America have assessed the performance of the TG/HDL-C ratio for IR [33,34], and this is the first one conducted in Peru. We found that the high TG/HDL-C ratio was associated with both IR and hyperinsulinemia after OGTT in a sample of healthy adults. Similarly, we found that TG/HDL-C ratio was positively correlated with the HOMA-IR and serum insulin after OGTT.

4.2. Comparison with other studies

Research conducted in adults with different clinical and sociodemographic conditions have shown favourable results when compared the TG/HDL-C ratio with the hyperinsulinemic-euglycemic clamp [42] and other biomarkers [33,34,43–52]. In this sense, some studies have reported a better performance of TG/HDL-C for the diagnosis of IR, compared to other lipid measures [44,47] and liver enzymes [46]. Nevertheless, discrepancies have been found in some studies that have simultaneously evaluated the performance of TG/HDL-C and the triglycerides and glucose index (TGI). For example, Abbasi (2011) did not find differences in their performance [43], while Du (2014) [44] and Mazidi (2018) [45] found that TGI was better.

On the other hand, some studies have reported that, although TG/HDL-C may be a useful surrogate marker for IR, it varies according to sex [34,46,50]. This suggests that a single cut-off point should not necessarily be used for all cases. Furthermore, ethnicity is a variable that also influences the performance of this ratio. In this sense, studies in African-Americans have shown that TG/HDL-C is not a reliable marker for IR [51,53,54]. Nevertheless, as previously mentioned, its usefulness has been demonstrated for other populations.

4.3. Results interpretation

It is already known that there is a highly significant relationship between IR and hypertriglyceridemia [1,24,25,27,55]. More specifically, it has been postulated that increased plasma TG concentrations and decreased of HDL-C are the key metabolic abnormalities in IR and are usually grouped under the name of “diabetic dyslipidaemia” [28,44,55]. Thus, it seems understandable that TG/HDL-C performs better than other lipid measures not only for IR, but also to identify increased cardiometabolic risk [44,47,55,56].

On the other hand, it is important to mention that despite the clinical usefulness of this ratio, discrepancies have been found according to sex [34,46,50] and ethnicity [51,53,54]. Likewise, there are studies that report a variable performance of TG/HDL-C when compared with other biomarkers [43–45]. First, from a physiological point of view, it is known that sexual [57] and race-ethnic [58,59] differences in lipid profiles are common. This is why Consensus Statements for metabolic syndrome use independent values for each of these two variables [31,32]. Second, TG/HDL-C performance variability may be due to the existence of different methods for the measurement of HDL-C, which still require standardization [34,60,61].

4.4. Relevance and implications

IR is a complex metabolic disorder that is strongly associated with several non-communicable diseases [4–16]. Since the hyperinsulinemic-euglycemic clamp and HOMA-IR present some limitations [17,19–22], it is necessary to have reliable, accessible and easy-to-measure alternatives [23], and one of them is the TG/HDL-C ratio.

As previously mentioned, both TG and HDL-C levels are strongly associated with metabolic syndrome [24–28] and increased cardiovascular risk [44,47,55,56]. Moreover, nowadays it is not uncommon for non-obese individuals to present metabolic disorders, such as IR [30,32]. Thus, timely screening would not only be beneficial for the population at risk, but also for normal-weight healthy subjects. In this sense, since practically the lipid profile has now become a routine test [62,63], the use of lipid biomarkers (e.g. TG/HDL-C) for the early detection of IR would be really useful.

4.5. Limitations

Some limitations must be highlighted. First, we did not assess causality between the evaluated variables due to the cross-sectional nature of our study. Second, we used information collected from medical records, which may have had errors at the time of being filled; nevertheless, we carried out a rigorous evaluation of the data quality to reduce the possibility of information bias. Third, we used HOMA-IR to measure IR and not the gold standard (hyperinsulinemic-euglycemic clamp); however, HOMA-IR is the most widely used alternative and previous studies have shown a very high correlation between these two measures. Fourth, this study was conducted in a single private medical centre, thus our results cannot be generalized to the Hispanic population; however, given the consistency of our findings with those described in other similar populations from Latin America, we believe that they could be extrapolated to populations of this region, except for African-American descendants.

5. Conclusions

High TG/HDL-C ratio was associated with both IR markers used in our study, in a sample of euthyroid normal-weight adults without T2DM. Prospective follow-up studies should corroborate these results using the gold standard and determine optimal cut-off points for different age groups and both sexes. Likewise, it is necessary to standardize a method for the measurement of HDL-C, in order to avoid biases in the calculation of the ratio.

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Competing interests

The authors have no potential competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dsx.2018.10.006.

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