Plasma triglyceride/HDL-cholesterol ratio, insulin resistance, and cardiometabolic risk in young adults

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Abstract Studies in mature adults suggest that the plasma concentration ratio of triglyceride (TG)/HDL-cholesterol (HDL-C) provides a simple way to identify apparently healthy individuals who are insulin resistant (IR) and at increased cardiometabolic risk. This study extends these observations by examining the clinical utility of the TG/HDL-C ratio and the metabolic syndrome (MetS) in 2,244 healthy college students (17–24 years old) of Mexican Mestizo ancestry. The TG/HDL-C ratio separating the 25% with the highest value was used to identify IR and increased cardiometabolic risk. Cardiometabolic risk factors were more adverse in men and women whose TG/HDL-C ratios exceeded 3.5 and 2.5, respectively, and approximately one third were identified as being IR. The MetS identified fewer individuals as being IR, but their risk profile was accentuated. In conclusion, both a higher TG/HDL-C ratio and a diagnosis of the MetS identify young IR individuals with an increased cardiometabolic risk profile. The TG/HDL-C ratio identified a somewhat greater number of "high risk" subjects, whereas the MetS found a group whose risk profile was somewhat magnified. These findings suggest that the TG/HDL-C ratio may serve as a simple and clinically useful approach to identify apparently healthy, young individuals who are IR and at increased cardiometabolic risk.—Murguía-Romero, M., J. R. Jiménez-Flores, S. C. Sigrist-Flores, M. A. Espinoza-Camacho, M. Jiménez-Morales, E. Piña, A. R. Méndez-Cruz, R. Villalobos-Molina, and G. M. Reaven. **Plasma triglyceride/HDL-cholesterol ratio, insulin resistance, and cardiometabolic risk in young adults. *J. Lipid Res.* 2013.** 54: **2795–2799.**

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Evidence has been presented that the plasma concentration ratio of triglyceride (TG)/HDL-cholesterol (HDL-C) may provide a relatively simple way to identify apparently healthy insulin-resistant persons with increased cardiometabolic risk (1, 2). However, there is evidence that the actual values of the ratio that best identifies such individuals will vary as a function of racial/ethnic background (3–7). More recently, it has also been shown that the most useful TG/HDL-C cut-point to identify cardiometabolic risk is not the same in men and women (2). However, there is essentially no information as to whether age also modifies the ability of the TG/HDL-C ratio to identify apparently healthy individuals with increased cardiometabolic risk. The primary goal of this analysis was to address this issue, and it is based on data obtained in an apparently healthy population of young men and women, mean age of 19 years. Second, since the diagnostic category of the metabolic syndrome (MetS) is commonly used to identify cardiometabolic risk in apparently healthy individuals (3, 8), our second goal was to compare these two approaches to identify insulin resistance (IR) and associated cardiometabolic risk in a population of young adults**.** In support of this effort is the recent observation that the plasma concentration ratio of TG/HDL-C was an independent determinant of arterial stiffness in adolescents and young adults (9).

SUBJECTS AND METHODS

This study presents results obtained from an epidemiological study from which data of a different nature have been published previously (10).

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Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; FPI, fasting plasma insulin; HDL-C, HDL-cholesterol; HOMA-IR, homeostasis model assessment - insulin resistance; IR, insulin resistant; MetS, metabolic syndrome; QUICKI, quantitative insulin sensitivity check index; SBP, systolic blood pressure; TG, triglyceride; WC, waist circumference.

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Participants

The study sample included 2,244 first-year university students (1,545 women and 699 men), 17–24 years of age, from the México City metropolitan area. Data were obtained by the Multidisciplinary Group to Investigate Health and Academic Performance (GMISARA) of the Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México (UNAM) (10). GMISARA employed a complex, multistage, geographic-area design for collecting data from public universities in the metropolitan area (UNAM and Universidad Autónoma de la Ciudad de México, UACM). All students were informed about the study, and they signed an informed consent. The protocol was approved by the Institutional Ethics Committee, and samples were collected over four years (2009–2012). Participants were not aware of any disease by medical history, nor did physical examination reveal any disease of relevance to this study. GMISARA members were trained to conduct interviews for collecting reliable data, including demographic, socioeconomic, dietary, and health-related information. Medical and physiological measurements were performed and collected by GMISARA medical personnel, and laboratory measurements were performed by CARPERMOR, S.A. de C.V., an internationally certified laboratory.

Study design

Measurement of cardiometabolic risk factors. Students fasted overnight and were seen at either UNAM or UACM between 7 AM and 10 AM. Waist circumference (WC) was determined while participants were upright, and it was measured to the nearest 0.1 cm at minimal respiration following normal expiration, with a flexible measuring tape placed at the high point of the iliac crest. Diastolic blood pressure (DBP) and systolic blood pressure (SBP) values were obtained after participants were resting quietly in a sitting position for 5 min, and determination of the maximum inflation level (up to four consecutive blood pressure readings) was obtained with a standard aneroid sphygmomanometer (Model DS44, Welch Allyn). The maximum values of replicate systolic and diastolic measurements provided estimates of blood pressure values. Glucose, insulin, TG, and HDL-C concentrations were determined by standard methods (CARPERMOR, S.A. de C.V.).

Criteria for subject classification. Men and women were divided into quartiles on the basis of their TG/HDL-C concentration ratios, and mean ± SD values were calculated. The 25% of the population with the highest TG/HDL-C ratio was defined as "abnormal," and values for age, homeostasis model assessment - insulin resistance (HOMA-IR); quantitative insulin sensitivity check index (QUICKI); SBP and DBP; body mass index (BMI); WC; and glucose, HDL-C, and TG concentrations were compared between this quartile and the remaining three quartiles.

HOMA-IR (11) and QUICKI (12) were used as surrogate estimates of insulin resistance, and the quartile with the highest value was defined as being insulin resistant, a classification based on results of a prospective study (13). The sensitivity and specificity of the TG/HDL-C ratio and the MetS to identify insulin resistance were calculated using as cut-points the values that separated the upper 25% of the TG/HDL-C ratio or a diagnosis of the MetS.

Criteria for diagnosing the MetS are those outlined in the "harmonized" version of the ATP III and IDF, in which at least three of the following five criteria must be satisfied (8): *1*) WC ≥ 90 cm in men and ≥ 80 cm in women; *2*) HDL-C < 40 mg/dl in men and < 50 mg/dl in women; *3*) TG ≥ 150 mg/dl; *4*) SBP ≥ 130 mmHg or DBP ≥ 85 mmHg; *5*) glucose ≥ 100 mg/dl and < 126 mg/dl.

Statistical analysis

The mean and SD were calculated separately in women and men for each experimental variable measured, and Student's *t* test was used to compare cardiometabolic risk factors. A cardiometabolic risk profile was generated by calculating the mean and SD of each measurement, dividing the men and women into two groups, stratified into those whose TG/HDL-C concentration ratio was in the upper quartile versus the lower 75%, and those who did or did not meet diagnostic criteria for the MetS.

The sensitivity and specificity (14) with which either the elevated TG/HDL-C ratio or the MetS identified the 25% of the population who were insulin resistant, as defined by HOMA-IR and QUICKI, were determined (15). Student's *t* test was performed using the R statistical language (16).

RESULTS

Demographic and metabolic characteristics of the study population are presented in **Table 1**. Note that every risk factor was accentuated in men. Table 1 also provides an estimate of the prevalence of conventional cardiometabolic risk factors in this young student population. Although only approximately 10% were obese by BMI criteria, the incidence of abdominal obesity was substantial, particularly

TABLE 1. Demographic and metabolic characteristics of the study population

				% of Young Adults with Altered Value[a]	
Variable	Women (n = 1,545)	Men (n = 699)	*P*	Women	Men
Age (years)	19 ± 2	20 ± 2	0.012		
HOMA-IR	2.39 ± 1.50	2.00 ± 1.27	<0.001		
QUICKI	0.34 ± 0.03	0.36 ± 0.03	<0.001		
BMI (kg/m^2)	24.1 ± 4.4	24.5 ± 4.5	0.053	9.5	13.4
WC (cm)	80 ± 11	85 ± 12	<0.001	48.2	28.6
SBP (mmHg)	103 ± 11	113 ± 12	<0.001	1.6	10.7
DBP (mmHg)	70 ± 8	76 ± 9	<0.001	4.0	11.3
Glucose (mg/dl)	89 ± 11	91 ± 11	<0.001	8.0	14.0
TG (mg/dl)	109 ± 55	125 ± 71	<0.001	16.1	24.3
HDL-C (mg/dl)	50 ± 10	46 ± 10	<0.001	49.1	24.9
TG/HDL-C ratio	2.21 ± 1.61	2.79 ± 1.76	<0.001		

Data are expressed as mean ± SD. *P* values are Student *t*-test for independent samples.

[a] BMI ≥ 30 kg/m^2; WC > 80 cm (women), > 90 cm (men); SBP ≥ 130 mmHg; DBP ≥ 85 mmHg; Glucose >100 mg/dl; TG ≥ 150 mg/dl; HDL-C < 50 mg/dl (women), < 40 mg/dl (men).

TABLE 2. Prevalence of insulin resistance as identified by the TG/HDL-C ratio or MetS

			HOMA-IR		QUICKI	
			Women	Men	Women	Men
			1,545 (100%)	699 (100%)	1,545 (100%)	699 (100%)
TG/HDL-C	Low	IR-no	915 (59.2)	448 (64.1)	897 (58.1)	447 (63.9)
		IR-yes	167 (10.8)	78 (11.2)	185 (12)	79 (11.3)
	High	IR-no	275 (17.8)	79 (11.3)	259 (16.8)	77 (11)
		IR-yes	188 (12.2)	94 (13.4)	204 (13.2)	96 (13.7)
MetS	Without MetS	IR-no	1123 (72.7)	504 (72.1)	1095 (70.9)	501 (71.7)
		IR-yes	226 (14.6)	93 (13.3)	254 (16.4)	96 (13.7)
	With MetS	IR-no	67 (4.3)	23 (3.3)	61 (3.9)	23 (3.3)
		IR-yes	129 (8.3)	79 (11.3)	135 (8.7)	79 (11.3)

For TG/HDL-C, low ⩽ 2.5 women, ⩽ 3.5 men; for TG/HDL-C high > 2.5 women, > 3.5 men. For IR-no, HOMA-IR ⩽ 2.9 women, ⩽ 2.5 men; QUICKI > 0.3265 women, > 0.3329 men; for IR-yes, HOMA-IR > 2.9 women, > 2.5 men, QUICKI ⩽ 0.3265 women, ⩽ 0.3329 men.

in the women. Blood pressure was higher in the men, as was the prevalence of prediabetes (fasting glucose ⩾ 100 mg/dl). Undiagnosed type 2 diabetes was limited to three men and one woman. The most prevalent abnormalities were high TG and low HDL-C concentrations, the former common in men and the latter in women.

The TG/HDL-C concentration ratios that marked the separation of the 25% of the participants with the highest ratios were ⩾ 2.43 and ⩾ 3.48 in women and men, respectively. Based upon these findings, TG/HDL-C concentration ratios of ⩾ 3.5 (men) and ⩾ 2.5 (women) were classified as "abnormal."

Table 2 presents the prevalence of IR in women and men who have either an abnormal TG/HDL-C or the MetS. When using HOMA-IR as the estimate of insulin action, the percentage of IR was greater in women who were identified by an abnormal TG/HDL-C ratio (n = 188, 12.2%) rather than the MetS (n = 129, 8.3%). The results in men were qualitatively comparable (13.4% versus 11.3%). The results were essentially identical when QUICKI was used as the estimate of IR. Thus, IR was more common when identified with the TG/HDL-C ratio than with MetS criteria, irrespective of which estimate of insulin resistance was used.

A more formal analysis of the ability of the two different criteria to identify insulin-resistant individuals is shown in **Table 3**. In women, the sensitivity of the TG/HDL-C ratio was greater in identifying insulin-resistant individuals than was the MetS, whereas the MetS had greater specificity. The same general observation held true in men, with the TG/HDL-C ratio having greater sensitivity but decreased specificity. These general findings were similar, irrespective of the use of HOMA-IR or QUICKI as the estimate of insulin resistance.

Tables 4 and **5** compare the cardiometabolic risk profiles of subjects identified because they had an abnormal TG/HDL-C ratio, versus those with a normal ratio, as well as those with and without the MetS. Focusing initially on the TG/HDL-C ratio, with the exception of age, all of the risk factors measured were significantly accentuated in those women (>2.5, Table 4) or men (>3.5, Table 5) with an abnormal ratio. Essentially identical results were seen when the cardiometabolic risk factors of those individuals, identified as the result of a diagnosis of the MetS, were compared with those without the MetS (Tables 4 and 5).

In this context, although an abnormal TG/HDL-C ratio was more common than the MetS in both women (463 versus 196) and men (173 versus 102), the magnitude of the difference between individuals with the MetS compared with those who did not meet the diagnostic criteria was greater than the differences between those with an abnormal or normal TG/HDL-C ratio. Since a significant number of women with an abnormal TG/HDL-C ratio also had the MetS (n = 168 out of 463; 36%) as did men (n = 83 out of 173; 48%), it did not seem appropriate to assign statistical significance to the magnitude of these differences in cardiometabolic risk factors, as a function of which criteria was used to identify the population. On the other hand, it seemed worthwhile to draw attention to these data. It is also of interest to note that relatively few

TABLE 3. Sensitivity and specificity with which TG/HDL-C ratio and MetS identify IR individuals

	Women		Men	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
IR determined with HOMA-IR[a]				
TG/HDL-C ratio > 2.5 women; TG/HDL-C ratio > 3.5 men)	53	77	55	85
MetS	36	94	46	96
IR determined with QUICKI[b]				
TG/HDL-C ratio > 2.5 women; TG/HDL-C ratio > 3.5 men)	52	78	55	85
MetS	35	95	45	96

[a] Insulin resistance defined as HOMA-IR > 2.9 women and HOMA-IR > 2.5 men.
[b] Insulin resistance defined as QUICKI ⩽ 0.3265 women and QUICKI ⩽ 0.3329 men.

TABLE 4. Cardiometabolic risk profile in women

	TG/HDL ratio		MetS	
	Women ⩽ 2.5	Women > 2.5	Women without MetS	Women with MetS
Variable	(n = 1082)	(n = 463)	(n = 1349)	(n = 196)
Age (years)	19.1 ± 1.7	19.6 ± 1.9 **	19.2 ± 1.7	19.8 ± 2.1 **
FPI (μU/ml)	9.5 ± 4.6	13.6 ± 8.4 **	9.8 ± 4.7	17.1 ± 10.7 **
HOMA-IR	2.1 ± 1.1	3.1 ± 2.0 **	2.2 ± 1.1	4.0 ± 2.5 **
QUICKI	0.35 ± 0.02	0.33 ± 0.02 **	0.35 ± 0.02	0.32 ± 0.02 **
BMI (kg/m^2)	23.2 ± 3.9	26.2 ± 4.9 **	23.5 ± 3.9	28.8 ± 4.7 **
WC (cm)	78.3 ± 9.9	85.2 ± 11.8 **	78.7 ± 10.0	92.0 ± 10.5 **
SBP (mmHg)	101.9 ± 10.2	106.6 ± 11.8 **	102.1 ± 10.3	111.6 ± 11.7 **
DBP (mmHg)	69.0 ± 7.9	72.1 ± 8.8 **	68.9 ± 7.7	76.7 ± 9.4 **
Glucose (mg/dl)	88.6 ± 8.4	91.2 ± 15.4 **	88.5 ± 8.1	95.7 ± 21.6 **
TG (mg/dl)	83.8 ± 21.7	168.7 ± 62.0 **	97.3 ± 36.6	191.8 ± 81.2 **
HDL-C (mg/dl)	53.5 ± 9.0	43.1 ± 7.3 **	51.7 ± 9.5	41.1 ± 6.3 **
TG/HDL-cholesterol ratio	1.6 ± 0.5	4.1 ± 2.3 **	2.0 ± 0.9	5.0 ± 3.1 **

Assessed by the TG/HDL-C ratio versus MetS. **$P < 0.001$.

women (2%) and men (3%) with a normal TG/HDL-C ratio had the MetS.

DISCUSSION

Several straightforward conclusions can be drawn from the results of this study. First, the data are consistent with earlier findings (15) that showed that the cut-points that separated the 25% individuals with the highest TG/HDL-C concentration ratio from the rest of the population were different in women than in men. Second, and perhaps surprisingly, the cut-points that identified the 25% of the college-aged women and men with the highest TG/HDL-C concentration ratios in this study were essentially identical to those reported in a group of middle-aged (mean age ~50 years) men and women (15). Third, in addition to being younger, the TG/HDL-C cut-points obtained in this study were established in a population primarily of Mexican Mestizo ancestry compared with a population with European ancestry (15). This latter finding is of interest in that the association of the TG/HDL-C ratio with fasting plasma insulin concentration was similar in non-Hispanic whites and Mexican-Americans (7). Furthermore, the TG/HDL-C ratio has been associated with IR in white obese teenagers and could be used along with other risk factors to identify subjects at increased risk of the appearance of IR-related morbidity (17).

On the other hand, the pragmatic use of the results of this study is not as clear and, to a large extent, depends upon the issue being pursued. For example, the sensitivity and specificity with which the TG/HDL-C ratio and the MetS identified insulin-resistant young individuals of Mexican-Mestizo origin was remarkably similar to values found in previous studies of middle-aged men and women of European ancestry (2, 15, 18, 19). Neither the TG/HDL-C ratio nor the MetS criteria identify IR individuals with great sensitivity, but both show reasonable specificity. Since the sensitivity and specificity of the two approaches to identify insulin-resistant individuals are comparable, use of the TG/HDL-C would cast a larger net than the MetS if the goal was to maximize the potential number of IR individuals to be captured.

However, if severity of the cardiometabolic risk factor profile is the goal, the MetS appeared to accomplish this task more effectively in this group of young college students. Thus, although both approaches demonstrated that the cardiometabolic risk profile was significantly accentuated in

TABLE 5. Cardiometabolic risk profile in men

	TG/HDL ratio		MetS	
	Men ⩽ 3.5	Men > 3.5	Men without MetS	Men with MetS
Variable	(n = 526)	(n = 173)	(n = 597)	(n = 102)
Age (years)	19.5 ± 1.8	19.5 ± 1.7	19.5 ± 1.7	19.2 ± 1.7 *
FPI (μU/ml)	7.5 ± 3.9	12.5 ± 6.3 **	7.7 ± 3.9	14.9 ± 6.7 **
HOMA-IR	1.7 ± 1.0	2.9 ± 1.5 **	1.7 ± 1.0	3.5 ± 1.6 **
QUICKI	0.36 ± 0.03	0.33 ± 0.03 **	0.36 ± 0.03	0.32 ± 0.02 **
BMI (kg/m^2)	23.5 ± 3.9	27.8 ± 4.6 **	23.6 ± 3.8	30.2 ± 4.1 **
WC (cm)	81.8 ± 10.3	93.6 ± 11.9 **	82.1 ± 9.9	100.4 ± 10.5 **
SBP (mmHg)	111.4 ± 11.6	118.0 ± 11.5 **	111.1 ± 10.9	124.3 ± 10.9 **
DBP (mmHg)	74.8 ± 8.7	78.6 ± 9.6 **	74.5 ± 8.2	83.1 ± 10.7 **
Glucose (mg/dl)	90.6 ± 11.2	92.8 ± 12.1 *	90.2 ± 11.2	97.1 ± 11.3 **
TG (mg/dl)	95.2 ± 29.4	215.2 ± 83.5 **	110.2 ± 53.1	210.7 ± 97.8 **
HDL-C (mg/dl)	48.8 ± 8.9	38.4 ± 6.9 **	47.6 ± 9.1	38.2 ± 7.9 **
TG/HDL-C ratio	2.0 ± 0.7	5.9 ± 3.1 **	2.5 ± 1.5	6.0 ± 3.8 **

Assessed by the TG/HDL-C ratio versus MetS. *$P < 0.05$; **$P < 0.001$.

the "abnormal" subset (the 25% with the highest TG/HDL-C ratio or the MetS), the results in Tables 4 and 5 suggest that the magnitude of difference between the "high-risk" group and the remainder was magnified when identified by the MetS.

The strengths of this study are that, for the first time, the potential utility of the TG/HDL-C ratio to identify apparently healthy individuals who are insulin resistant and at enhanced cardiometabolic risk was evaluated in college-aged students of Mexican-Mestizo origin rather than a middle-aged population of European ancestry. In addition, the findings were obtained from a reasonably large population (n = 2,244). The obvious weakness is the absence of any outcome data. However, despite these shortcomings, we would argue that our results are of interest in that values of the TG/HDL-C ratio separating the 25% of college-aged men and women with the highest ratios from the remainder of the experimental population were essentially identical to those reported in middle-aged men and women (2, 15, 18, 19). Furthermore, this was the case despite the substantial racial/ethnic differences (European versus Mexican-Mestizo ancestry) in this study compared with earlier ones. Both the TG/HDL-C cut-points and a diagnosis of MetS were able to identify IR individuals, whose associated cardiometabolic risk profile was significantly more adverse than the remainder of the population. However, the two approaches differed in that the TG/HDL-C ratio identified a greater number of "high-risk" subjects, consistent with findings in white obese teenagers (17), whereas the MetS criteria seemed to find a group whose cardiometabolic risk profile was somewhat accentuated.

In conclusion, the results of this study show that TG/HDL-C cut-points based on findings in middle-aged men and women of European ancestry can identify apparently healthy Mexican-Mestizo individuals who are insulin resistant and at increased cardiometabolic risk. In addition, data were presented comparing the relative abilities of the TG/HDL-C ratio and the MetS to accomplish these tasks. Given this information, the individual clinician/investigator can use the approach that seems most relevant to their clinical/research interests.

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