Evaluation of Lipid Ratios and Triglyceride-Glucose (TyG) Index as Risk Markers of Insulin Resistance in Iranian Polycystic Ovary Syndrome (PCOS) Woman

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Abstract

Background: Insulin resistance has a key role in the pathophysiology of polycystic ovary syndrome (PCOS). Previous investigations have informed that some lipid ratios could be a simple clinical indicator of insulin resistance (IR) in some disorders and ethnicities. We aimed to examine the correlation between triglyceride to HDL-cholesterol (TG/HDL-C), total cholesterol to HDL-cholesterol (TC/HDL-C) and fasting triglyceride-glucose (TyG) indices with IR (as measured by homeostasis model assessment of IR [HOMA-IR], quantitative insulin sensitivity check index [QUICKI] and fasting glucose to insulin ratio [FGIR]), and determine a good clinical predictor for IR in Iranian PCOS woman.

Methods: We evaluated 305 PCOS women. After physical evaluations, biochemical parameters were measured using commercial kits and TG/HDL-C, TC/HDL-C and TyG indices were calculated using formula. Fasting insulin level measured using ELISA technique. IR was defined as a HOMA-IR value ≥2.63, FG-IR<8.25 and QUICKI <0.33.

Results: The insulin-resistance and insulin-sensitive groups, which established by HOMA-IR, FG-IR and QUICKI values, were different in terms of TG/HDL-C, TC/HDL-C and TyG indices. These indices were associated with IR after adjusting for age and BMI. The under ROC curves (AUC) of TyG, TG/HDL-C and TC/HDL-C for predicting HOMA-IR index were 0.639, 0.619 and 0.623 respectively which were significant, with a p-value 0.012, 0.033 and 0.027, respectively. The AUC of TC/HDL-C (0.614) was significant (p-value 0.04) for predicting FG-IR.

Conclusion: Our findings demonstrated that the elevated TyG, TG/HDL-C and TC/HDL-C were significantly associated with IR and could be utilized as indicators of IR among PCOS women in Iran.

1. Introduction

Polycystic ovary syndrome (PCOS) is a complex hormonal disorder common in reproductive-aged women that characterized by ovulation dysfunction, overproduction of androgens and polycystic ovarian morphology (PCOM) under B-ultrasound [1]. The prevalence of PCOS is approximately 5–15% which is the most common cause of infertility in women [1].

PCOS share many features with the metabolic syndrome so that the majority of PCOS women (44–85%) (10,51) have insulin resistance (IR) and the compensatory hyperinsulinemia regardless of BMI [2–4]. Taken together, increasing insulin and androgen levels can interrupt follicle growth which in turn can lead to the irregular menstrual cycle, an-ovulatory subfertility and accumulation of immature follicles [2, 5]. Although the pathogenesis of PCOS is not completely known yet, growing body of evidence has shown that IR has a central role in the pathophysiology of PCOS and is associated with great risk of metabolic disorders including type 2 diabetes mellitus (T2DM), dyslipidemia, nonalcoholic fatty liver disease (NAFLD) and cardiovascular disease (CVD) [6]. It has been demonstrated that the modulation of IR causes a significant improvement in PCOS complications [7, 8]. Therefore, it is of paramount importance to evaluate IR in this at risk population.

The reference standard to diagnose IR is the hyperinsulinemic euglycemic glucose clamp technique [9], but it is time-consuming, labor-intensive, costly, and technically challenging [10]. So, the surrogate markers including homeostasis model assessment for insulin resistance (HOMA-IR), the quantitative insulin sensitivity check index (QUICKI) and the fasting glucose to insulin ratio (FGIR) have emerged to estimate of IR [11]. The clinical efficacy of these surrogate markers has been limited because of the absence of standardization, cost and availability of the insulin assay technique [12]. Hence, for daily clinical practice, a simple and more available marker for predicting IR can be valuable and cost-effective for early detection of people with IR for clinicians [12].

Previous evidences have been suggested that the fasting triglyceride-glucose (TyG) index and the triglyceride to high-density lipoprotein cholesterol (TG/HDL-C) concentration ratio are closely associated with IR [13–15]. Some studies have shown that total cholesterol to HDL-C (TC/ HDL-C) concentration ratio also related to IR and risk of CVD [15]. It is worth noting that the association between lipid ratios and IR may differ by ethnicity and some indices may not be applicable to predict IR in particular populations [16–18]. Furthermore, there are a few studies dealing with the association between IR and lipid ratios among PCOS subjects in the Iranian population. This first comprehensive study was carried out to investigate the association of TG/HDL-C, TC/HDL-C and TyG indices with IR (as estimated by HOMA-IR, QUICKI and FG-IR) and to determine the diagnostic utility of these markers in recognizing IR among PCOS women in Iran.

2. Materials And Methods

2.1 Study participants

A total of 305 PCOS women were recruited from Shahid Bahonar Hospital, Kerman, Iran. Participants' ages ranged from 20 to 40 years, with body mass index (BMI) of 17–35 kg/m^2. PCOS diagnosis was according to the Rotterdam criteria [19] which includes: PCOM on ultrasound, hyperandrogenism, and oligo- or an-ovulation. Exclusion criteria were including the following: the presence of hypertension, pregnancy, and history of endocrine disorders or CVD. The present research was approved by the Ethical Committee of Kerman University of Medical Sciences (IR. KUM.REC.1399.208), and carried out according to the declaration of Helsinki. Informed consent was essential before enrolling a participant in our study.

2.2 Anthropometric and laboratory measurements

BMI was calculated using a standard formula [body weight (kg)/height (m^2)]. Blood samples were taken after an 8-hr fasting period at the follicular phase of their menstrual cycle. Biochemical parameters including, fasting blood sugar (FBS), total cholesterol (TC), triglyceride (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C), were evaluated using commercial kits (Pars Azmoon, Iran). Fasting insulin level was measured using ELISA kit (Monobind Inc.). Follicle-stimulating hormone (FSH), luteinizing hormone (LH), free T4, and homocysteine levels were evaluated

using ELISA kits (Pishtaz Teb, Iran), according to manufacturer's instructions. Details about the intra-assay coefficients of variation (CV) for biochemical parameters have been previously reported [20].

We defined the TG/HDL-C, TC/HDL-C and TyG indices using the following calculations respectively: TG (mg/dL)/HDL-C (mg/dL), TC (mg/dL)/HDL-C (mg/dL) and Ln[TG (mg/dL) × FBS (mg/dL)]/2.

IR was defined as a HOMA-IR value ≥ 2.63, FG-IR < 8.25 and QUICKI < 0.33. We used these cut-off points based on previous studies [21, 22]. Although the gold standard to evaluate IR is the hyperinsulinemic euglycemic clamp, estimating markers including HOMA-IR, FG-IR and QUICKI are correlated with it. HOMA-IR was calculated utilizing [FBG (mg/dL)] × [fasting insulin (μU/ml)]/405 [23]. FG-IR was calculated as fasting glucose (mg/dl)/fasting insulin (μU/ml) and QUICKI was calculated as 1/(log fasting insulin [μU/ml] + log glucose [mg/dl]) [23]. The patients were divided into insulin-resistant (IR) and insulin-sensitive (IS) groups based on HOMA-IR, FG-IR and QUICKI. First, clinical and biochemical parameters were compared between the two groups. Then, the correlation of these parameters with HOMA-IR, FG-IR and QUICKI were analyzed.

2.3 Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics 16.0 (IBM SPSS, Chicago, IL). The normality of the variables was determined using the Shapiro–Wilk test. Continuous variables with normal distribution were presented as mean ± SD, while skewed variables were presented as median and interquartile range (IQR). Statistical difference between IR and IS group was assessed using Student's T test and Mann–Whitney U test. For correlation analysis, Pearson or Spearman analysis was calculated. To assess the ability of lipid ratios and TyG for predicting insulin resistance according to HOMA-IR and FG-IR in PCOS patients logistic regression and receiver operator characteristic (ROC) curve analyses were used.

3. Results

3.1 Clinical and biochemical parameters of the study population

General characteristics, biochemical parameters and hormonal features of the patients in the IR and the IS groups are shown in Table 1. The mean age and BMI of subjects were 29.94 ± 4.56 years and 26.62 ± 4.19 kg/m^2, respectively.

Table 1
Clinical and biochemical parameters of the study population according to FG-IR and HOMA-IR (positive and negative).

		FG-IR			HOMA-IR		
Variables	**Total PCOS**	**Negative n = 275 (≥ 8.25)**	**Positive n = 30 (< 8.25)**	**p-value**	**Negative n = 275 (< 2.63)**	**Positive n = 30 (≥ 2.63)**	**p-value**
Age	29.94 ± 4.56	29.82 ± 4.55	31.1 ± 4.51	0.14	29.85 ± 4.56	30.77 ± 4.52	0.29
BMI	26.62 ± 4.19	26.62 ± 4.16	26.63 ± 4.51	0.98	26.66 ± 4.22	26.22 ± 4.01	0.58
Insulin	4.34 (2.8–7.4)	4 (2.67–6.41)	13.2 (11.9-14.83)	< 0.001	4 (2.67–6.41)	13.2 (12.15–14.83)	< 0.001
HomoCys	11.57 (8.87–15.4)	11.9 (9.07–15.4)	9.92 (7.97–14.02)	0.077	11.7 (9.19–15.4)	9.83 (7.68–13.47)	0.04
Free_T	3.25 ± 1.15	3.25 ± 1.13	3.21 ± 1.38	0.84	3.26 ± 1.15	3.14 ± 1.2	0.59
LH	6.48 (4.25–9.45)	6.48 (4.4–9.5)	6.05 (3.46–8.6)	0.21	6.48 (4.4–9.5)	6.46 (3.44–8.63)	0.34
FSH	6 (4.44–7.55)	6 (4.47–7.54)	6.15 (4-8.79)	0.91	6 (4.47–7.5)	6.6 (4.07–8.83)	0.75
TG	116 (86–156)	116 (86–156)	117 (81-156.75)	0.71	114 (84–155)	125 (105-205.65)	0.07
FBS	89.57 ± 9.48	89.58 ± 9.53	89.4 ± 9.15	0.92	88.69 ± 8.87	97.6 ± 11.16	< 0.001
TC	172.46 ± 36.24	171.56 ± 36.7	180.72 ± 31.1	0.18	171.59 ± 36.26	180.46 ± 35.69	0.20
LDL-C	98.54 ± 29.08	98.64 ± 29.54	97.63 ± 24.86	0.85	98.12 ± 29.01	102.38 ± 29.86	0.44
HDL-C	44 (38-49.6)	44 (38–50)	43 (36.25–46.25)	0.18	44 (39–50)	41 (34–47)	0.048
TyG	4.62 (4.62 ± 0.24)	4.62 ± 0.24	4.63 ± 0.23	0.73	4.61 ± 0.23	4.74 ± 0.25	0.005

The cutoff point for QIUCKI based on 90% percentile was 0.33 (positive < 0.33). Parametric data are shown as mean ± standard deviation. Non-parametric data are given as median and interquartile range [Q1-Q3]

		FG-IR			HOMA-IR		
TG/HDL-C	2.68 (1.84–3.78)	2.68 (1.84–3.72)	2.73 (1.85–4.71)	0.75	2.66 (1.81–3.69)	3.32 (2.18-5)	0.033
TC/HDL-C	4 ± 1.13	3.95 ± 1.12	4.44 ± 1.15	0.024	3.94 ± 1.09	4.55 ± 1.36	0.005
FG-IR	20.76 (11.9-20.76)	21.79 (13.78–34.46)	7.07 (5.57–7.57)	< 0.001	21.79 (13.78–34.46)	7.48 (5.57–8.46)	< 0.001
HOMA-IR	0.98 (0.61–1.65)	0.89 (0.56–1.43)	3.1 (2.6–3.41)	< 0.001	0.89 (0.56–1.42)	3.14 (2.93–3.5)	< 0.001
QUICKI	0.39 ± 0.05	0.4 ± 0.04	0.32 ± 0.01	< 0.001	0.4 ± 0.04	0.32 ± 0.01	< 0.001

The cutoff point for QIUCKI based on 90% percentile was 0.33 (positive < 0.33). Parametric data are shown as mean ± standard deviation. Non-parametric data are given as median and interquartile range [Q1-Q3]

9.83 percent of PCOS patients had HOMA-IR ≥ 2.63, FG-IR < 8.25 and QUICKI < 0.33 constituted the IR group. The IR and IS groups, which defined by HOMA-IR, FG-IR and QUICKI values, did not differ in terms of age, BMI, Free T4, LH, FSH, TG, TC, LDL-C (Table 1). The results between two groups based on QUICKI not shown due to the similarity to FG-IR. Fasting insulin concentration, TC/HDL-C and HOMA-IR were significantly higher ($p < 0.001$), and FG-IR and QUICKI were significantly lower ($p < 0.001$) in the FG-IR and QUICKI positive group compared to their counterparts (Table 1). In regard to IR and IS groups based on HOMA-IR, FBS, fasting insulin concentration, TyG, TC/HDL-C, TG/HDL-C and HOMA-IR were significantly higher and homocysteine, HDL-C, FG-IR and QUICKI were significantly lower in IR group.

3.2 The correlation between FG-IR, QUICKI and HOMA-IR indices with clinical and biochemical parameters

Table 2 shows the correlations between FG-IR, QUICKI and HOMA-IR indices with clinical and biochemical parameters with and without adjusting for age and BMI. The variables including, insulin, TG, TC, TyG, TC/HDL-C and TG/HDL-C were significantly negatively associated with

Table 2
The correlation between FG-IR, QUICKI and HOMA-IR indices with clinical and biochemical parameters.

	FG-IR		QUICKI		HOMA-IR	
Variables	**unadjusted**	**adjusted**	**unadjusted**	**adjusted**	**unadjusted**	**adjusted**
Age	0.048 (0.4)	-	0.017 (0.77)	-	0.04 (0.48)	-
BMI	-0.03 (0.6)	-	-0.06 (0.28)	-	0.04 (0.44)	-
Insulin	-0.762 (< 0.001)	-0.765 (< 0.001)	-0.871 (< 0.001)	-0.872 (< 0.001)	0.983 (< 0.001)	0.98 (< 0.001)
HomoCys	0.168 (0.003)	0.172 (0.003)	0.128 (0.025)	0.134 (0.019)	-0.145 (0.01)	-0.149 (0.009)
Free_T	-0.04 (0.4)	-0.038 (0.5)	-0.013 (0.81)	-0.011 (0.84)	-0.026 (0.65)	-0.025 (0.66)
LH	0.01 (0.86)	0.01 (0.8)	0.035 (0.54)	0.03 (0.6)	-0.068 (0.23)	-0.061 (0.28)
FSH	0.04 (0.41)	0.04 (0.43)	0.037 (0.52)	0.036 (0.53)	-0.004 (0.94)	-0.005 (0.93)
TG	-0.143 (0.013)	-0.144 (0.012)	-0.163 (0.004)	-0.16 (0.005)	0.17 (0.003)	0.165 (0.004)
FBS	-0.039 (0.5)	-0.036 (0.5)	-0.33 (< 0.001)	-0.327 (< 0.001)	0.331 (< 0.001)	0.329 (< 0.001)
TC	-0.164 (0.004)	-0.165 (0.004)	-0.173 (0.002)	-0.172 (0.003)	0.174 (0.002)	0.171 0.003)
LDL-C	-0.06 (0.26)	-0.069 (0.23)	-0.07 (0.22)	-0.069 (0.23)	0.063 (0.27)	0.057 (0.32)
HDL-C	0.08 (0.14)	0.079 (0.17)	0.1 (0.06)	0.099 (0.08)	-0.119 (0.038)	-0.116 (0.044)
TyG	-0.163 (0.004)	-0.165 (0.004)	-0.241 (< 0.001)	-0.238 (< 0.001)	0.233 (< 0.001)	0.227 (< 0.001)
TG/HDL-C	-0.15 (0.009)	-0.151 (0.009)	-0.187 (0.001)	-0.183 (0.001)	0.214 (< 0.001)	0.209 (< 0.001)
TC/HDL-C	-0.175 (0.002)	-0.175 (0.002)	-0.207 (< 0.001)	-0.202 (< 0.001)	0.249 (< 0.001)	0.245 (< 0.001)

FG-IR and QUICKI and significantly positively associated with HOMA-IR before and after adjusting for age and BMI. The variable, homocysteine and HDL-C were statistically significantly negatively associated with HOMA-IR. Homocysteine was also significantly positively correlated to FG-IR and QUICKI. Although

FBS concentration was not correlated to FG-IR, it was significantly negatively correlated to QUICKI and significantly positively correlated to HOMA-IR.

3.3 Association between lipid profile, lipid ratios and TyG index with IR

Table 3 shows the 2 models of the association between FG-IR and HOMA-IR indices with lipid profiles, TyG, TC/HDL-C, TG/ HDL-C through multiple logistic regression analyses. In model 1, the odds ratios (OR) were calculated without adjusting. In model 2, the ORs were calculated after adjusting for age and BMI.

Table 3
Association between FG-IR and HOMA-IR with lipid profiles, TyG, TC/HDL-C and TG/HDL-C indices.

		FG-IR		HOMA-IR	
	Variables	OR (95% CI)	p-value	OR (95% CI)	p-value
Unadjusted models	HomoCys	0.926 (0.851–1.008)	0.075	0.907 (0.831–0.991)	0.03
	TG	1.001 (0.995–1.008)	0.7	1.006 (1-1.011)	0.062
	TC	1.007 (0.997–1.017)	0.189	1.007 (0.996–1.017)	0.2
	LDL-C	0.999 (0.986–1.012)	0.85	1.005 (0.992–1.018)	0.44
	HDL-C	0.963 (0.92–1.008)	0.1	0.954 (0.91–1.001)	0.054
	TyG	1.325 (0.268–6.553)	0.73	10.832 (2.015–58.236)	0.005
	TG/HDL-C	1.117 (0.905–1.377)	0.3	1.295 (1.065–1.575)	0.009
	TC/HDL-C	1.43 (1.044–1.958)	0.026	1.551 (1.134–2.123)	0.006
adjusted models for age and BMI	HomoCys	0.928 (0.855–1.008)	0.078	0.909 (0.832–0.992)	0.033
	TG	1.001 (0.995–1.007)	0.77	1.006 (1-1.012)	0.061
	TC	1.007 (0.996–1.017)	0.19	1.007 (0.996–1.017)	0.2
	LDL-C	0.998 (0.984–1.011)	0.71	1.005 (0.992–1.018)	0.49
	HDL-C	0.961 (0.919–1.006)	0.086	0.952 (0.908–0.998)	0.04
	TyG	1.225 (0.239–6.288)	0.8	11.621 (2.109–64.03)	0.005
	TG/HDL-C	1.109 (0.897–1.37)	0.33	1.304 (1.07–1.59)	0.009
	TC/HDL-C	1.429 (1.04–1.961)	0.027	1.574 (1.145–2.165)	0.005

In model 1, homocysteine (0.907, 95% CI [0.831–0.991]), TG/HDL-C (1.295, 95% CI [1.065–1.575]), TC/HDL-C (1.551, 95% CI [1.134–2.123]) and TyG (10.832, 95% CI [2.015–58.236]) were associated with HOMA-IR index and TC/HDL-C (1.43, 95% CI [1.044–1.958]) was associated with FG-IR index.

In model 2 homocysteine (0.902, 95% CI [0.832–0.992]), TG/HDL-C (1.304, 95% CI [1.07–1.59]), TC/HDL-C (1.57, 95% CI [1.145–2.165]) and TyG (11.622, 95% CI [2.109–64.03]) were also associated with HOMA-IR index and TC/HDL-C (1.429, 95% CI [1.04–1.961]) was also associated with FG-IR index.

3.4 ROC analysis

Figure 1 shows the ROC curve for TyG, TG/HDL-C and TC/HDL-C indices as predictors for HOMA-IR and FG-IR. The AUC of TyG, TG/HDL-C and TC/HDL-C for predicting HOMA-IR index were 0.639, 0.619 and 0.623, respectively, which were significant, with a p-value 0.012, 0.033 and 0.027 respectively, as shown in Table 4. Although the AUC of TyG, TG/HDL-C were not significant, the AUC of TC/HDL-C (0.614) was significant (p-value 0.04) for predicting FG-IR, as shown in Table 4. In addition, the AUC of lipid profile (TG, TC, LDL-C and HDL-C) were not significant for predicting HOMA-IR and FG-IR (Fig. 1S).

Table 4
The areas under ROC curve (AUC), sensitivity, specificity by the optimized cut-off points for TyG, TC/HDL-C and TG/HDL-C indices in predicting HOMA-IR and FG-IR indices.

	Variables	AUC	p-value	95% Confidence Interval
HOMA-IR	**TyG**	0.639	0.012	(0.531–0.747
	TG/HDL-C	0.619	0.033	(0.508–0.730)
	TC/HDL-C	0.623	0.027	(0.510-0.0736)
FG-IR	**TyG**	0.517	0.75	(0.408–0.627)
	TG/HDL-C	0.548	0.38	(0.434–0.662)
	TC/HDL-C	0.614	0.04	(0.514–0.713)

4. Discussion

A growing body of evidence indicates that PCOS is a metabolic disease which IR has a central role in the pathogenesis and complications of its [24]. Therefore, evaluation of IR in PCOS women is very critical and helpful. Direct and indirect methods (HOMA-IR, QUICKI and FG-IR) for IR assessment are complex, expensive and not suitable for epidemiological studies [24]. Hence, there is an urgent need to develop an easy-to-measure, more reasonable and cost-effective method for IR measurements to contribute to diagnosis, treatment, and prognosis of PCOS [24].

Dyslipidemia is one of the most confusing metabolic consequences with a prevalence of up to 70% in PCOS women [25]. Although, the cause of lipidemic abnormalities in PCOS is multifactorial, IR plays most

important pathophysiological role in disturbed lipid metabolism and dyslipidemia that is mediated through stimulation of lipolysis and changed expression of lipoprotein lipase and hepatic lipase [25]. Recently, some studies have proposed that lipid ratios may be useful alternative markers for IR estimation in different races [7].

The findings of the current study demonstrated that the TG/ HDL-C, TC/HDL-C and TyG indices are strongly correlated with IR as estimated by HOMA-IR, FG-IR and QUICKI in PCOS women in Iran. A high value of these ratios was positively correlated to HOMA-IR and negatively correlated to FG-IR and QUICKI before and after adjusting for BMI and age. Although dyslipidemia was not seen in IR group (except HDL-C based on HOMA-IR), TG/HDL-C, TC/HDL-C and TyG ratios were significantly higher in subjects with HOMA-IR index ≥ 2.63 (IR positive) as compared to those with HOMA-IR index < 2.63 (IR negative), and also TC/HDL-C ratio was significantly lower in IS subjects as measured with FG-IR and QUICKI. These findings result from a comprehensive analysis between TG/HDL-C, TC/HDL-C and TyG indices with several indices of IR suggest that these ratios might be more useful indicators of IR than lipid profiles. To the best of our knowledge, this is the first comprehensive study to investigate these relationships in Iranian PCOS patients.

In this context, some studies have also reported the performance of these ratios for IR. The positive correlation of TG/HDL-C, TC/HDL-C with HOMA-IR has been demonstrated among PCOS women in China [24] and T2DM in Thailand [26]. Results of some studies also supported that TG/HDL-C ratio could be used as an indicator of IR among some population including the middle-aged and elderly population in Taiwan [16], euthyroid normal-weight healthy adults in Peru [27], PCOS patients in India [28] and in Chinese population without diabetes [29]. A large scale cross-sectional analysis among Chinese adults also indicated that TG/HDL-C ratio and TyG index are useful markers in estimating IR and TyG index is the best indicator for assessing the risk of IR [30]. However, it is important to highlight that, in spite of clinical effectiveness of these ratios, inconsistencies have been identified according to ethnicity [27]. For example, researches in African-Americans have revealed that TG/HDL-C is not a reliable indicator for IR [31–33].

To the best of our knowledge, only one previous study has been directed in this regard on 36 infertile women with PCOS in Iranian population and confirmed a significant association in TC/HDL-C, TG/HDL-C and LDLC/HDL-C ratios with IR (as estimated by HOMA-IR) in PCOS patients [7]. Another Iranian study has been conducted on 5201 non diabetic persons and noted that TG/HDL-C and TC/HDL-C serve as independent predictors of incident diabetes, during ≈ 6 years follow up [34]. Although these studies demonstrated the efficiency of lipid ratios for IR prediction, there was a lack of sufficient documents concerning lipid ratios and TyG index in PCOS women in the Iranian population. Moreover, most studies in this area were based on HOMA-IR and they have not considered FG-IR and QUICKI as two well-known indicators for IR. Therefore, in the present study to assess the diagnostic ability of lipid profile, TG/HDL-C, TC/HDL-C, and TyG in classifying insulin resistance, ROC curve analysis was applied using control cutoff values for HOMA-IR and FG-IR (*i.e.* 2.63 and 8.25 respectively). Despite lipid profile did not show sufficient predictability for IR, the AUC of TG/HDL-C, TC/HDL-C, and TyG based on HOMA-IR and FG-IR was greater

than 0.5 and considered acceptable test performance. Thus, it seemed that these ratios are effective and beneficial diagnostic indicators for IR in PCOS. These data were consistent with prior evidence in Iran supporting the diagnostic potential of TC/HDL-C and TG/HDL-C for PCOS [7]. Even though in a previous study the AUC value of TG/HDL-C was the highest based on HOMA-IR, in the current study the AUC value of TyG was the highest based on HOMA-IR and the AUC value of TC/HDL-C was the highest based on FG-IR. This discrepancy could be partially due to the larger sample size in our study. Although the diagnostic accuracy of the TyG index has been described in some populations [35–37] the current study is the first analyzing that assessed the diagnostic ability of TyG in Iranian PCOS woman.

As a strength, this study was the first comprehensive study, which investigated different metabolic index for estimating of IR -as assessed using HOMA-IR, FG-IR and QUICKI- in PCOS women in Iran. It must be noted that the limitations of the current study included the lack of direct IR evaluation and the fact that patients were evaluated only once, so that within-subject biological variation of biochemical parameters measurements could not therefore be minimized.

In conclusion, TG/HDL-C, TC/HDL-C and TyG indices are valuable indicators to predict IR in Iranian PCOS women. These markers can be easily calculated because lipid profile and glucose values can be received from routine laboratory tests and analytically and financially available to all clinical laboratories. Therefore, we suggested the application of TG/HDL-C, TC/HDL-C and TyG indices in risk assessments for IR in Iranian PCOS women and future epidemiologic researches.

Declarations

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1975 Helsinki declaration as revised in 2008.

Conflict of interest

The authors declare that they have no conflict of interest.

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Availability of data and materials

The datasets used or analysed during the current study are available from the corresponding author on reasonable request.

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Figures

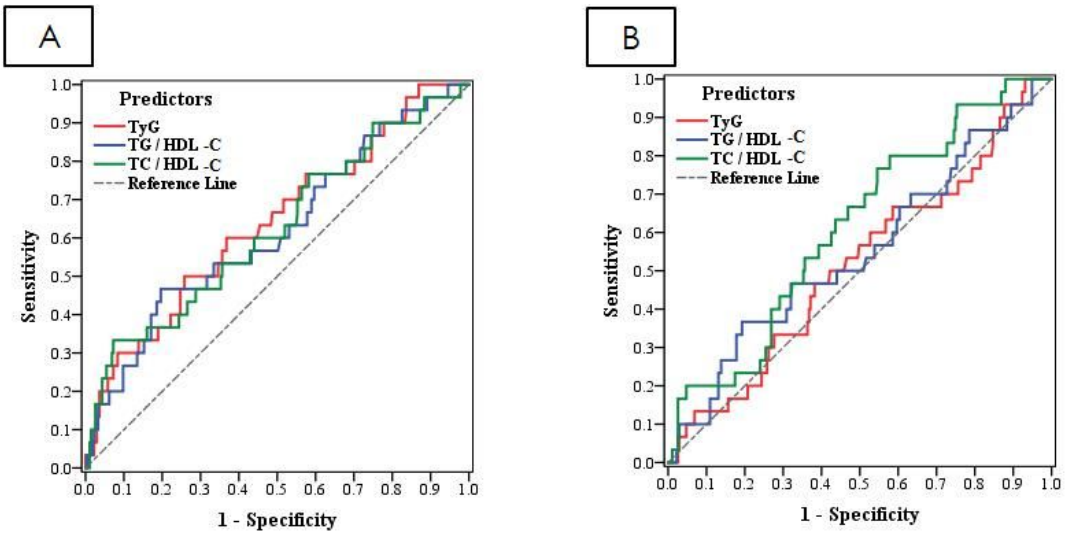

Figure 1

The ROC curve analysis results for the predictability of TyG, TC/HDL-C, and TG/HDL-C indices in classifying insulin resistance considering (A) HOMA-IR and (B) FG-IR in PCOS patients.

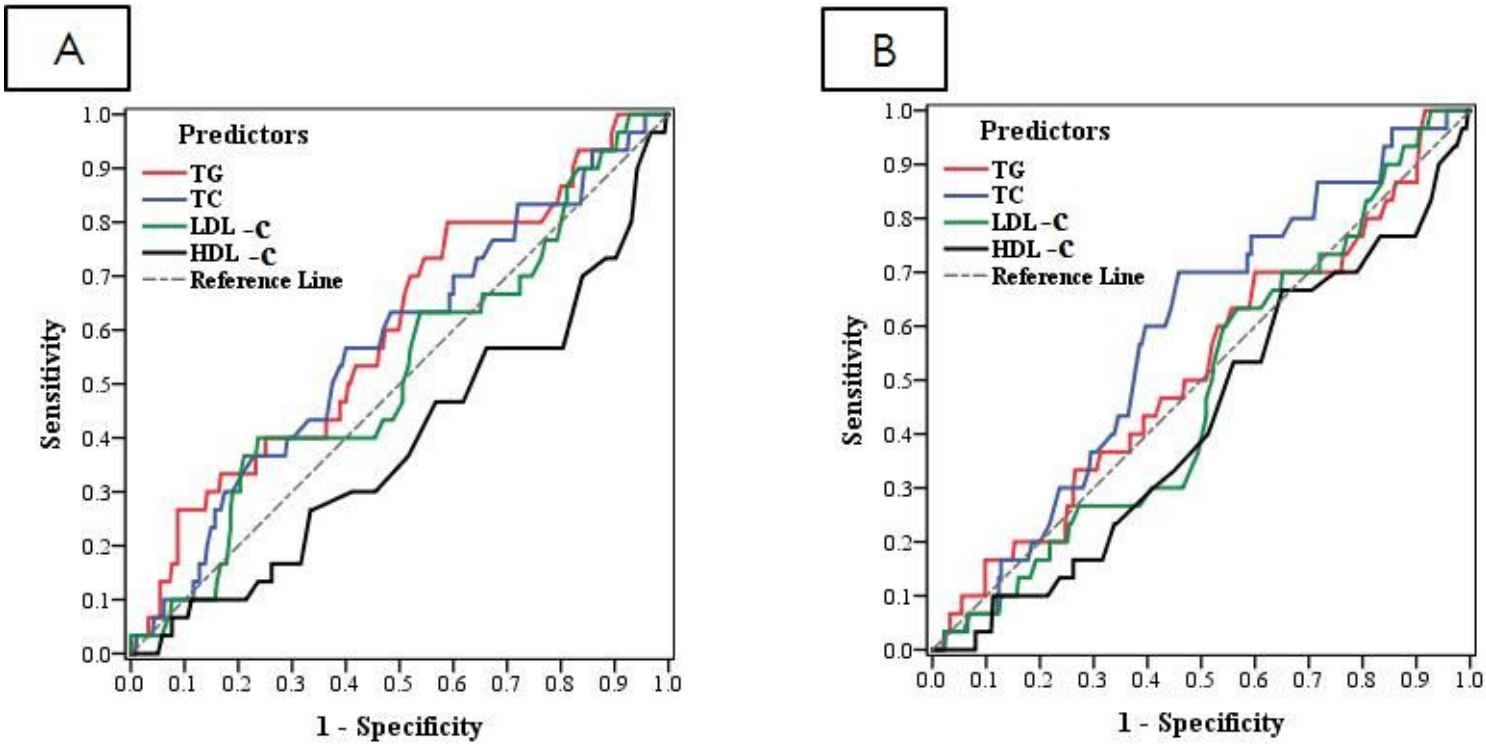

Figure 2

The ROC curve analysis results for the predictability of lipid profiles in classifying insulin resistance considering (A) HOMA-IR and (B) FG-IR in PCOS patients.