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Investigating the efficiency of novel indicators in predicting risk of metabolic syndrome in the Iranian adult population

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Abstract:

BACKGROUND: Whether new anthropometric indicators are superior to conventional anthropometric indicators and whether they can better identify MetS in apparently healthy people needs further research. Thus, this study aimed to estimate the efficiency of novel indicators in predicting the risk of metabolic syndrome (MetS) in the Iranian adult population.

MATERIAL AND METHODS: In this cross-sectional study, 800 subjects were selected by clustered random sampling. The metabolic factors, traditional and novel anthropometric indices, the triglyceride and glucose index (TyG index) and modified TyG indices (TyG-BMI, TyG-WC, TyG-WHR, and TyG-WHtR), and metabolic score for insulin resistance (METS-IR) were evaluated. The MetS was calculated according to the IDF criteria. To investigate the risk ofMetS, logistic regression was used along with modeling.

RESULTS: In all three models, all traditional anthropometric indices were associated with MetS ($P < 0.001$). Regarding novel anthropometric indices, all indices (except for ABSI) significantly predicted the risk of MetS in all participants before and after adjustment ($P < 0.001$). WTI index presented the highest Odds ratios for MetS (29.50, 95% CI: 15.53–56.03). A positive association was found in all models between TyG and modified TyG indices and METS-IR with MetS (P for all < 0.001). TyG-WHtR index presented the highest Odds ratios for MetS (70.07, 95% CI: 32.42–151.43).

CONCLUSION: A combination of the TyG index and WHtR (TyG-WHtR index) was better than the TyG index alone, with a higher odds ratio in predicting MetS. Due to the simplicity of these indices, cost-effectiveness, and facility at small-scale labs and being predictive of MetS risk it is suggested to include these markers in clinical practice.

Keywords:

Anthropometry, Iran, metabolic syndrome, obesity

Introduction

Metabolic syndrome (MetS) consists of a set of metabolic disorders and risk factors for cardiovascular diseases (CVDs) and type 2 diabetes mellitus, with symptoms such as abdominal obesity, hyperglycemia, insulin resistance, dyslipidemia, and hypertension.[1-3] MetS increases the risk of heart disease up to two times and type 2 diabetes up to five times.[4] Today, this syndrome is prevalent all around the world and is introduced as an important health concern. The global prevalence of this disease in adults is estimated at 25%, depending on factors such as living area, age, sex, and lifestyle.[5,6] In the Middle East and South Asia, the prevalence of MetS is higher than the global average, and in Iran, it is reported as 30.4% in adults.[7] The etiology of MetS is complex and results from the

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interaction of genetic and environmental factors. This syndrome is considered a public health challenge in the world due to the sedentary lifestyle, increased energy intake, increased obesity, and in other words, the modern world's lifestyle.[6] Abdominal obesity, as one of the main components of MetS, is the most important risk factor for heart disease, which is often associated with increased metabolic abnormalities such as high blood pressure, dyslipidemia, and insulin resistance.[8] The literature indicated that weight gain and obesity could increase the risk of MetS. On the other hand, weight loss is associated with reducing the risk of MetS and related risk factors.[9-11] For defining obesity, several anthropometric indices are used. In recent years, there have been more investigations about the factors for better risk prediction of CVDs.[12] Some studies have found statistical evidence about the priority of abdominal obesity indices [such as waist circumference (WC), waist-to-height ratio (WHtR), and waist-to-hip ratio (WHR)] in determining the risk factors of heart diseases over body mass index (BMI).[13-15] New anthropometric indices have been constructed recently for screening MetS, including abdominal volume index (AVI), A body shape index (ABSI), body adiposity index (BAI), lipid accumulation index (LAP), body roundness index (BRI), Universidad de Navarra-body adiposity estimator (CUN-BAE), triponderal mass index (TMI), conicity index (CI), metabolic score for insulin resistance (METS-IR), and triglyceride-glucose (TyG) index.[16-20] Implementation of these indicators has several advantages, including ease of use, low cost, common use in both men and women, and previous applications in various populations.[21] However, whether these new anthropometric indicators are superior to conventional anthropometric indicators and whether they can better identify MetS in apparently healthy people needs further research. Since the efficiency of novel anthropometric indicators has not been investigated in the Iranian adult military population, the present study was designed to investigate the prevalence of MetS and its related risk factors based on International Diabetes Federation (IDF) criteria, assessment of the efficiency of novel indicators in predicting risk of MetS in the employees of a military center in Iran.

Materials and Methods

Study design and setting

The present study was a cross-sectional study conducted on the employees of a military center between May and September 2022.

Study participants and sampling

At first, 800 subjects were included in the survey using clustered random sampling, and 50 of them were excluded from the study according to the inclusion and exclusion criteria. The inclusion criteria included a willingness to participate in the study, both sexes between 18 and 60 years old. The exclusion criteria included unwillingness to participate in the study, pregnancy and breastfeeding, incompleteness of demographic or anthropometric information, following special diets, taking special drugs due to a specific disease such as fatty liver, thyroid, cancer, HIV, and infectious diseases, consumption of smoking and alcohol, and taking special supplements in the last 3 months.

Data collection tool and technique

Measurement of anthropometric indices

In the current study, weight was measured using a digital scale made in Japan with an accuracy of 0.1 kg, without shoes and with the least possible clothing. A tape measure with an accuracy of 0.5 cm was used to measure the height. The WC was calculated from the upper part of the iliac crest and above the navel, and the hip circumference (HC) was measured from the most prominent part of the hip area using a tape measure. BMI was calculated using the formula (weight in kilograms/height in meters squared).[22,23] Also, WHR was obtained by dividing WC by HC. A trained expert performed all measurements.

Formulas for calculating novel anthropometric indices and AIP[24-26]

Waist-to-height ratio (WHtR) = WC (cm)/height (cm)

Weight-adjusted-waist index (WWI) = WC (cm)/$\sqrt{}$weight (kg)

Body roundness index (BRI) =364.2 − 365.5 × 1 – WC (cm)/2 π^2 × 0.5 height (m)

$$\text{A body shape index(ABSI)} = \frac{\text{wc}}{height^{1/2} \times \text{BMI}^{2/3}}$$

Abdominal volume index (AVI) = [2 (WC^2) + 0.7(waist/hip)^2]/1000

$$\text{Body adiposity index (BAI)} = \frac{\text{hip}}{\text{height}^{1.5}} - 18$$

$$\text{Conicity index (CI)} = \frac{\text{WC(m)}}{0.109\sqrt{\frac{\text{weight(kg)}}{\text{height(m)}}}}$$

Lipid accumulation product (LAP) for men=[WC(cm)–65]×[triglyceride(mM)]

Lipid accumulation product (LAP) for women=[WC(cm)–58]×[triglyceride(mM)]

Waist circumference-triglyceride index (WTI) = Ln [TG (mg/dl).WC (cm)/2]

Tri-ponderal mass index (TMI) = weight (kg)/height (m^3)

Atherogenic index of plasma (AIP) = Log TG/HDL-C

Calculation of TyG index and modified TyG indices[27,28]

Triglyceride and glucose index (TyG index) = Ln [TG (mg/dl) × FBG (mg/dl)/2]

TyG-BMI = TyG index × BMI

TyG-WC = TyG index × WC (cm)

TyG-WHR = TyG index × WHR

TyG-WHtR = TyG index × WHtR

METS-IR = Ln [(2 × FBG) + TG)] × BMI/Ln (HDL-C)

Blood pressure (BP) assessment

After the patients rested for 20 minutes, the BP was recorded between 8:00 and 9:00 AM by the same nurse who performed the blood sampling. This work was repeated three times in a row, and the average of three consecutive measurements was calculated.

Calculation of pulse pressure (PP) and mean arterial pressure (MAP)[29]

Pulse pressure (PP)(mmHg) = systolic blood pressure (SBP) (mmHg) –diastolic blood pressure (DBP) (mmHg)

Mean arterial pressure (MAP)(mmHg)=[SBP+(2×DBP)]/3

Biochemical measurements

In this study, after 12 hours of fasting, 5 cc of blood was taken from each person to measure serum levels of fasting blood glucose (FBG) and lipid profile including triglyceride (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and very low-density lipoprotein (VLDL). FBG and lipid profile were measured by enzymatic method and using the Pars Azmoon Kit made in Iran.

Definition of MetS

According to the criteria of the International Diabetes Federation (IDF), MetS is defined as the presence of central obesity or a WC ≥95 cm for both sexes (according to the Iranian National Obesity Committee)[30] plus two or more of the following four factors: TG ≥150 mg/dl or drug treatment, HDL-C <40 mg/dl in men and less than <50 mg/dl in women or drug treatment, SBP/DBP ≥130/85 or drug treatment, and FBG ≥100 mg/dl or drug treatment.[4]

Calculation of sample size

According to Maleki *et al*.'s study[31] and the prevalence of MetS in the Iranian adult population (4.4%), the initial sample size in this study was 720 subjects with a confidence error (d = 1.5%) and a confidence level of 95% according to the formula $(n = (z_{1-a/2})^2 . p (1 - p)/d^2)$. With a drop of 10%, the final sample size was considered 800 subjects.

Statistical analysis

In this study, the normal distribution of the data was evaluated using the Kolmogorov-Smirnov statistical test. The Independent *t*-test was used to compare quantitative variables in two groups, and the Chi-square test was used to compare qualitative variables. To investigate the risk of MetS, logistic regression was used along with modeling (crude model and models with adjustment of the effect of confounding factors such as age, gender, education, marital status, and medications). All quantitative data are expressed as mean ± standard deviation and qualitative data are expressed as numbers (percentages) and SPSS version 19 software was used for data analysis. A P value less than 0.05 was considered as a significant level.

Ethical consideration

The research protocol was in accordance with the guidelines of the Declaration of Helsinki. The Ethics Committee in Research of Baqiyatullah University of Medical Sciences approved the study protocol (Ethical code: IR.BMSU.REC.1401.020, Approval date: 2022-05-10). The informed written consent form was completed for all subjects at the beginning of the study.

Results

Fifty participants were excluded due to a lack of inclusion criteria. The prevalence of MetS, according to IDF criteria, was 17.46% in the sample. The mean age of the participants was 39.27 ± 7.57 years. The characteristics of the subjects without MetS and with MetS groups are presented in Table 1. Of the 750 participants studied, 635 (84.67%) were males and 115 (15.33%) were females. The height, ABSI, marital status, education, and gender of without and with MetS groups were not significantly different ($P \geq 0.05$).

Subjects with MetS had significantly higher age ($P = 0.008$), SBP, DBP, MAP, PP, weight, BMI, WC, HC, WHR, WHtR, AVI, CI, LAP, BAI, BRI, WWI, WTI, TMI, FBG, TG, VLDL, TC, LDL-C, LDL-C.HDL-C ratio, AIP, TyG, TyG-BMI, TyG-WC, TyG-WHR, TyG-WHtR,

Table 1: The characteristics of the subjects in the without and with MetS groups

Variables	Non-MetS (*n*=619)	MetS (*n*=131)	*P*
Age (y)	38.93±7.65	40.87±6.99	0.008
Gender			0.41*
Female (*n*)	98 (85.2)	17 (14.8)	
Male (*n*)	521 (82)	114 (18)	
Total	619 (82.5)	131 (17.5)	
Education			0.80*
Diploma (*n*) (%)	298 (81.6)	67 (18.4)	
Associate degree (*n*) (%)	92 (84.4)	17 (15.6)	
BSc (*n*) (%)	196 (83.8)	38 (16.2)	
MSc (*n*) (%)	22 (75.9)	7 (24.1)	
PhD (*n*) (%)	11 (84.6)	2 (15.4)	
Total	619 (82.5)	131 (17.5)	
Marital status			0.57*
Single (*n*) (%)	72 (84.7)	13 (15.3)	
Married (*n*) (%)	547 (82.3)	118 (17.7)	
Total	619 (82.5)	131 (17.5)	
SBP (mmHg)	119.94±6.78	126.08±10.14	<0.001
DBP (mmHg)	76.92±6.97	81.84±8.37	<0.001
MAP (mmHg)	91.26±6.41	96.59±8.66	<0.001
PP (mmHg)	43.02±5.47	44.23±5.22	0.02
Traditional anthropometric indices			
Weight (kg)	77.09±11.41	89.11±9.67	<0.001
Height (cm)	173.65±7.75	175.00±7.39	0.06
BMI (kg/m^2)	25.51±3.05	29.12±2.96	<0.001
WC (cm)	88.72±8.94	100.58±5.21	<0.001
HC (cm)	95.44±9.00	107.60±5.22	<0.001
WHR	0.92±0.01	0.93±0.02	0.006
Novel anthropometric indices			
WHtR	0.51±0.05	0.57±0.03	<0.001
ABSI (m11/6 kg-2/3)	0.078±0.006	0.079±0.005	0.16
AVI	15.90±3.20	20.29±2.16	<0.001
CI	1.22±0.09	1.29±0.05	<0.001
LAP	35.84±21.96	90.13±37.44	<0.001
BAI (kg/m^2)	23.83±4.57	28.59±3.27	<0.001
BRI	5.07±0.28	5.40±0.17	<0.001
WWI	10.14±0.86	10.68±0.51	<0.001
WTI	8.53±0.47	9.23±0.40	<0.001
TMI	14.72±1.91	16.69±2.07	<0.001
Biochemical parameters			
FBG (mg/dl)	92.63±11.04	110.58±29.81	<0.001
TG (mg/dl)	127.91±62.27	220.09±86.79	<0.001
VLDL (mg/dl)	25.58±12.45	44.01±17.35	<0.001
TC (mg/dl)	177.90±38.42	204.29±44.30	<0.001
HDL-C (mg/dl)	44.31±7.77	38.69±5.47	<0.001
LDL-C (mg/dl)	107.05±33.15	121.11±41.06	<0.001
LDL-C.HDL-C ratio	2.49±0.92	3.16±1.09	<0.001
AIP	0.42±0.22	0.72±0.19	<0.001
TyG and modified TyG indices			
TyG	8.57±0.47	9.30±0.46	<0.001
TyG-BMI	219.05±30.50	271.10±30.18	<0.001
TyG-WC	761.23±89.69	936.57±70.04	<0.001
TyG-WHR	7.96±0.47	8.70±0.50	<0.001

Contd...

Table 1: Contd...

Variables	Non-MetS (*n*=619)	MetS (*n*=131)	*P*
TyG-WHtR	4.38±0.52	5.35±0.39	<0.001
METS-IR	38.82±5.55	48.51±5.60	<0.001

Values are expressed as means±SD. *P*<0.05 was considered as significant using Independent *t*-test for comparison between the two groups. **P*<0.05 was considered as significant using Chi-square test. BSc; Bachelor of Science, MSc; Master of Sciences, PhD; Doctor of Philosophy, MetS; metabolic syndrome, BMI; body mass index, WC; waist circumference, HC; hip circumference, WHR; waist-to-hip ratio, SBP; systolic blood pressure, DBP; diastolic blood pressure, MAP; mean arterial pressure; PP; pulse pressure; FBG; fasting blood glucose, TG; triglyceride, TC; total cholesterol, HDL-C; high-density lipoprotein cholesterol, LDL-C; low-density lipoprotein cholesterol, VLDL; very low-density lipoprotein, AIP; atherogenic index of plasma, WHtR; waist to height ratio, ABSI; a body shape index; AVI; abdominal volume index; BAI; body adiposity index, BRI; body roundness index, CI; conicity index, LAP; lipid accumulation production, WWI; weight-adjusted-waist index, WTI; waist circumference-triglyceride index, TMI; tri-ponderal mass index, TyG index; triglyceride and glucose index, METS-IR; metabolic score for insulin resistance. Central obesity: Obese for male and female (WC ≥95 cm) or normal (WC <95), FBG: high (≥100 mg/dl) or normal (<100 mg/dl), TG: high (≥150 mg/dl) or normal (<150 mg/dl), HDL-C: low (<50 mg/dl for female and <40 mg/dl for male) or normal (≥50 mg/dl for female and ≥40 mg/dl for male), SBP/DBP: high (≥130/85 mmHg) or normal (<130/85 mmHg)

and METS-IR (*P* for all <0.001) and had significantly lower HDL-C (*P* < 0.001).

As shown in Table 2, according to the IDF criteria, the prevalence of central obesity (38.4%), high TG (41.1%), low HDL-C (34.3%), and hypertension (11.3%) were significantly higher in males than in females (*P* for all <0.05).

Odds ratios (95% CI) for MetS (dependent variables) according to traditional anthropometric indices (independent variables among participants) are shown in Table 3. In all three models, all traditional anthropometric indices (weight, BMI, WC, HC, and WHR) correlated with MetS (*P* for all <0.05).

Regarding novel anthropometric indices, all indices (except for ABSI) significantly predicted the risk of MetS in all participants before and after adjustment (*P* for all <0.001). WTI index presented the highest Odds ratios for MetS (29.50, 95% CI: 15.53–56.03) [Table 4].

Odds ratios (95% CI) for MetS according to TyG, modified TyG indices, and METS-IR are presented in Table 5. A positive association was found in all models between TyG, modified TyG indices, and METS-IR with MetS (*P* for all <0.001). TyG-WHtR index presented the highest Odds ratios for MetS (70.07, 95% CI: 32.42–151.43).

Discussion

In the present study, the prevalence of MetS was 17.5%. All traditional anthropometric indices were associated with MetS. Regarding novel anthropometric indices, all indices (except for ABSI) significantly predicted the risk of MetS in all participants before and after adjustment. WTI index presented the highest Odds ratios for MetS. A positive association was found in all models between TyG and modified TyG indices and METS-IR with MetS. TyG-WHtR index presented the highest Odds ratios for MetS.

The application of anthropometric parameters is one of the new and low-cost diagnostic tools of MetS. It seems novel anthropometric indices can represent MetS better than conventional anthropometric indices.[18] Some studies establish that WC and BMI indices supply confined data regarding fat distribution. WC is indistinct to what extent depends on body size and a raised waistline alone is insufficient to identify visceral obesity and consequently the MetS risk.[32,33] BMI is a rough index of obesity because subjects with similar BMI may exhibit different grades of fatness.[34,35] However, no consensus has been agreed upon about the best anthropometric indices for predicting the MetS. In this cross-sectional analytical study, we assessed and compared the predictive ability of novel and traditional anthropometric indices and the triglyceride and glucose index (TyG index) and modified TyG indices in identifying MetS. Wu *et al*. compared conventional and novel indices for predicting MetS in Chinese adults and concluded that the novel anthropometric index could identify MetS in non-overweight/obese people. The authors recommended WHtR as an early primary screening method for MetS in non-overweight/obese people.[18] In another cross-sectional study that examined the ability of novel and traditional anthropometric indices to predict the risk of MetS and its components in Peruvian adults, BRI performed similarly to or better than BMI and WC at predicting MetS and MetS components.[36] Quaye *et al*. found that WC and BMI did not help to predict MetS and its components in females, whereas novel indices such as AVI and CI could predict MetS in females.[37] The most effective anthropometric indicator for identifying MetS varies across sex and age.[21]

In the present study, except for ABSI, all obesity indices had the capacity to predict MetS. ABSI, proposed by Krakauer *et al*., is based on WC but is independent of height and BMI.[38] Consistent with our finding, a cross-sectional study by Guo *et al*. indicated that, except for ABSI, other anthropometric indices could identify MetS in middle-aged patients with diabetes.[21] Some studies also have shown that ABSI was weak in predicting cardiovascularCVD and MetS.[18,38-40] Some studies have demonstrated that ABSI performs better than BMI and WHtR as a visceral adiposity index to predict metabolic diseases.[41-43] Leone *et al*. found that

Table 2: Comparison between the qualitative risk factors of MetS in two groups of men and women according to the IDF criteria

Variables	Female (*n*=115)	Male (*n*=635)	*P**
Central obesity			0.03
Yes (*n*) (%)	32 (27.8)	244 (38.4)	
No (*n*) (%)	83 (72.2)	391 (61.6)	
Total	115 (100)	635 (100)	
FBS			
High (*n*) (%)	33 (28.7)	196 (30.9)	0.64
Normal (*n*) (%)	82 (71.3)	439 (69.1)	
Total	115 (100)	635 (100)	
TG (*n*) (%)			
High (*n*) (%)	21 (18.3)	261 (41.4)	<0.001
Normal (*n*) (%)	94 (81.7)	374 (58.9)	
Total	115 (100)	635 (100)	
HDL-c			<0.001
Low (*n*) (%)	75 (65.2)	218 (34.3)	
Normal (*n*) (%)	40 (34.8)	417 (65.7)	
Total	115 (100)	635 (100)	
SBP/DBP (mmHg)			0.02
High (*n*) (%)	5 (4.3)	72 (11.3)	
Normal (*n*) (%)	110 (95.7)	563 (88.7)	
Total	115 (100)	635 (100)	

Table 3: Odds ratios (95% CI) for MetS according to traditional anthropometric indices

Variables	Or (CI)	B	**P*
Weight			
Model 1[a]	1.09 (1.07–1.12)	0.09	<0.001
Model 2[b]	1.10 (1.08–1.13)	0.10	<0.001
Model 3[c]	1.10 (1.07–1.12)	0.09	<0.001
BMI			
Model 1[a]	1.42 (1.32–1.52)	0.35	<0.001
Model 2[b]	1.42 (1.32–1.53)	0.35	<0.001
Model 3[c]	1.40 (1.30–1.51)	0.33	<0.001
WC			
Model 1[a]	1.20 (1.16–1.24)	0.18	<0.001
Model 2[b]	1.20 (1.16–1.24)	0.18	<0.001
Model 3[c]	1.19 (1.15–1.23)	0.17	<0.001
HC			
Model 1[a]	1.19 (1.15–1.23)	0.17	<0.001
Model 2[b]	1.19 (1.15–1.23)	0.17	<0.001
Model 3[c]	1.18 (1.15–1.23)	0.17	<0.001
WHR			
Model 1[a]	1.16 (1.05–1.27)	0.14	0.002
Model 2[b]	1.15 (1.04–1.27)	0.14	0.004
Model 3[c]	1.12 (1.005–1.24)	0.11	0.04

**P*<0.05 statistically significant by Multivariable logistic regression. a. model 1: unadjusted. b. model 2: adjusted for age and gender. c. model 3: adjustment for age, gender, education, marital status, and medications

the inclusion of ABSIz amended the prediction of MetS compared to BMIz alone in obese Caucasian children and adolescents.[33] Also, TMI is a new anthropometric index for predicting body fat percentage and MetS, which is suggested to have similar or better performance than BMI.[44,45] In line with previous studies, the results of this study showed that both BMI and TMI increased the risk of MetS, but the TMI's ability to predict risk was greater.

In the present study, WTI and TyG-WHtR indices presented the highest Odds ratios for MetS.

Yang *et al*. indicated that the waist circumference (WT) index, calculated as WC (cm)×TG (mmol/L), was associated with the coronary heart disease score and, therefore, considered the WT index a strong predictor of coronary heart disease.[46] Furthermore, the WT index showed an effective indicator for the screening of MetS in people with type 2 diabetes.[47] Recently, Liu *et al*. developed another form of WT index termed WTI (calculated as Ln [TG (mg/dL) WC (cm)/2]), which represented a strong ability to identify MetS.[24] In a study by Endukuru *et al*., compared to other novel indices, WTI had the highest predictive ability to detect low HDL-C, elevated BP, and high TG in women. Moreover, the participants in the fourth quartile of WTI displayed the highest odds ratios for low HDL-C and high TG.[48] Other studies also found that WTI has a high predictive capacity to discriminate MetS.[49,50]

Recently, the METS-IR has been developed by Bello-Chavolla OY *et al*. to evaluate insulin sensitivity validated against the euglycemic–hyperinsulinemic clamp. It was correlated to ectopic fat accumulation and it could predict incident T2D.[51] It has been reported that METS-IR is strongly associated with hypertension in the normal-weight population.[52] In the present study also METS-IR significantly predicted the risk of MetS in all participants before and after the adjustment.

In this study, a combination of the TyG index and WHtR (TyG-WHtR index) was better than the TyG index alone, with a higher odds ratio in predicting MetS. TyG index, a product of triglyceride and fasting plasma glucose, is a novel index that can distinguish people with MetS. Similar to our findings, in a cross-sectional study, the TyG index effectively identified MetS, and the product of the TyG index and anthropometric indices improved the identification and prediction of MetS. Before and after adjustment, TyG-WHtR presented the highest OR in all participants.[53] A study with data obtained from the Korean National Health and Nutrition Examination Survey from 2007–2010 showed integration of the TyG index and anthropometric indices predicted insulin resistance (the underlying disorder in MetS) better than TyG alone. They found that TyG-BMI, a combination of the TyG index and BMI, implemented better than the other indices with a higher Odds ratio.[54] Some studies have assessed combined TyG index and obesity indices for insulin resistance or diabetes, such as TyG-WC or TyG-BMI, and detected that combined parameters are more efficient than the TyG index alone.[55,56] Elevated

Table 4: Odds ratios (95% CI) for MetS according to novel anthropometric indices

Variables	Or (CI)	B	*P
WHtR			
Model 1[a]	1.29 (1.23–1.36)	0.25	<0.001
Model 2[b]	1.31 (1.24–1.38)	0.27	<0.001
Model 3[c]	1.29 (1.23–1.37)	0.26	<0.001
WWI			
Model 1[a]	2.30 (1.78–2.96)	0.83	<0.001
Model 2[b]	2.48 (1.90–3.25)	0.91	<0.001
Model 3[c]	2.45 (1.84–3.26)	0.89	<0.001
ABSI			
Model 1[a]	1.23 (0.91–1.67)	0.21	0.16
Model 2[b]	1.26 (0.92–1.71)	0.23	0.13
Model 3[c]	1.34 (0.96–1.87)	0.29	0.08
AVI			
Model 1[a]	1.57 (1.45–1.71)	0.45	<0.001
Model 2[b]	1.58 (1.45–1.71)	0.45	<0.001
Model 3[c]	1.56 (1.43–1.70)	0.44	<0.001
BAI			
Model 1[a]	1.27 (1.21–1.33)	0.24	<0.001
Model 2[b]	1.32 (1.25–1.40)	0.28	<0.001
Model 3[c]	1.31 (1.23–1.38)	0.27	<0.001
CI			
Model 1[a]	1.09 (1.06–1.11)	0.08	<0.001
Model 2[b]	1.09 (1.06–1.11)	0.08	<0.001
Model 3[c]	1.09 (1.06–1.11)	0.08	<0.001
LAP			
Model 1[a]	1.06 (1.05–1.07)	0.06	<0.001
Model 2[b]	1.06 (1.05–1.07)	0.06	<0.001
Model 3[c]	1.06 (1.05–1.07)	0.06	<0.001
BRI			
Model 1[a]	1.67 (1.52–1.85)	0.51	<0.001
Model 2[b]	1.72 (1.55–1.90)	0.54	<0.001
Model 3[c]	1.68 (1.51–1.88)	0.52	<0.001
WTI			
Model 1[a]	29.65 (16.51–53.24)	3.38	<0.001
Model 2[b]	34.46 (18.60–63.85)	3.54	<0.001
Model 3[c]	29.50 (15.53–56.03)	3.38	<0.001
TMI			
Model 1[a]	1.56 (1.41–1.73)	0.44	<0.001
Model 2[b]	1.65 (1.47–1.84)	0.50	<0.001
Model 3[c]	1.65 (1.48–1.85)	0.50	<0.001

*P<0.05 statistically significant by Multivariable logistic regression. a. model 1: unadjusted. b. model 2: adjusted for age and gender. c. model 3: adjustment for age, gender, education, marital status, and medications

TG may be associated with the raised transport of free fatty acids to the liver, causing an increment in hepatic glucose output. Hence, the TyG index, a TG and glucose product, can predict insulin resistance better than other indicators.[54,57] The superiority of obesity indices remains controversial. The inconsistency in the literature might be due to differences in the anthropometric indices selected for analysis, gender, ethnic and racial, underlying disease, age of participants, and different confounder variables.

Table 5: Odds ratios (95% CI) for MetS according to TyG index, modified TyG indices, and METS-IR

Variables	Or (CI)	B	*P
TyG index			
Model 1[a]	27.18 (15.23–48.52)	3.30	<0.001
Model 2[b]	30.38 (16.61–55.55)	3.41	<0.001
Model 3[c]	26.10 (13.95–48.82)	3.26	<0.001
TyG-BMI			
Model 1[a]	1.05 (1.04–1.06)	0.05	<0.001
Model 2[b]	1.05 (1.04–1.06)	0.05	<0.001
Model 3[c]	1.05 (1.04–1.06)	0.05	<0.001
TyG-WC			
Model 1[a]	1.02 (1.02–1.03)	0.02	<0.001
Model 2[b]	1.03 (1.02–1.03)	0.03	<0.001
Model 3[c]	1.03 (1.02–1.03)	0.02	<0.001
TyG-WHR			
Model 1[a]	26.67 (14.88–48.04)	3.28	<0.001
Model 2[b]	29.38 (15.94–54.15)	3.38	<0.001
Model 3[c]	25.07 (13.30–47.24)	3.22	<0.001
TyG-WHtR			
Model 1[a]	79.41 (37.59–167.75)	4.37	<0.001
Model 2[b]	86.32 (40.25–185.12)	4.45	<0.001
Model 3[c]	70.07 (32.42–151.43)	4.25	<0.001
METS-IR			
Model 1[a]	1.35 (1.28–1.42)	0.30	<0.001
Model 2[b]	1.35 (1.28–1.42)	0.30	<0.001
Model 3[c]	1.32 (1.26–1.40)	0.28	<0.001

*P<0.05 statistically significant by Multivariable logistic regression. a. model 1: unadjusted. b. model 2: adjusted for age and gender. c. model 3: adjustment for age, gender, education, marital status, and medications

Limitation and recommendation

Our study has several limitations. First, the present study has a cross-sectional design and cannot reflect causality. Hence, studies with prospective designs are required to confirm these relationships over longer periods. In addition, due to differences in standards criteria (WHO, IDF, ATP III, and AHA/NHLBI) used to definition of MetS and inconsistencies in the cut-off values, our findings are not generalizable. The lack of data pertaining to the lifestyle of the participants was another limitation of the present study. However, despite the aforementioned limitations, there were several strengths that merit acknowledgment. Indeed, assessment of both conventional and novel anthropometric indices, the inclusion of both sexes in the study, and use of multivariable logistic regression in three different models provided a robust platform to interrogate the incumbent data. Studies with prospective designs are required to confirm these findings.

Conclusions

In the present study, except for ABSI, all obesity indices had the capacity to predict MetS. WTI and TyG-WHtR indices presented the highest Odds ratios for MetS. Due to the simplicity of these indices, cost-effectiveness, and facility at small-scale labs and being predictive of MetS risk it is suggested to include these markers in clinical practice.

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Conflicts of interest

There are no conflicts of interest.

References

1. Eckel RH, Alberti KG, Grundy SM, Zimmet PZ. The metabolic syndrome. Lancet 2010;375:181-3.
2. Tol A, Pourreza A, Shojaeezadeh D, Mahmoodi M, Mohebbi B. The assessment of relations between socioeconomic status and number of complications among type 2 diabetic patients. Iran J Public Health 2012;41:66.
3. Barati S, Sadeghipour P, Ghaemmaghami Z, Mohebbi B, Baay M, Alemzadeh-Ansari MJ, *et al*. Warning signals of elevated prediabetes prevalence in the modern Iranian urban population. Prim Care Diabetes 2021;15:472-9.
4. Alberti KG, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, Donato KA, *et al*. Harmonizing the metabolic syndrome: A joint interim statement of the international diabetes federation task force on epidemiology and prevention; national heart, lung, and blood institute; American heart association; world heart federation; international atherosclerosis society; and international association for the study of obesity. Circulation 2009;120:1640-5.
5. Saklayen MG. The global epidemic of the metabolic syndrome. Curr Hypertens Rep 2018;20:1-8.
6. Handelsman Y. Metabolic syndrome pathophysiology and clinical presentation. Toxicol Pathol 2009;37:18-20.
7. Farmanfarma KK, Kaykhaei MA, Adineh HA, Mohammadi M, Dabiri S, Ansari-Moghaddam A. Prevalence of metabolic syndrome in Iran: A meta-analysis of 69 studies. Diabetes Metab Syndr 2019;13:792-9.
8. Higgins V, Adeli K. Pediatric metabolic syndrome: Pathophysiology and laboratory assessment. Ejifcc 2017;28:25-42.
9. Hadaegh F, Azizi F. Effect of weight change on incident of metabolic syndrome and its components according to Iranian waist circumference and NHLBI: TLGS. Iran. J. Endocrinol. Metab 2010;12:116-30.
10. Kukkonen-Harjula KT, Borg PT, Nenonen AM, Fogelholm MG. Effects of a weight maintenance program with or without exercise on the metabolic syndrome: A randomized trial in obese men. Prev Med 2005;41:784-90.
11. Lofgren IE, Herron KL, West KL, Zern TL, Brownbill RA, Ilich JZ, *et al*. Weight loss favorably modifies anthropometrics and reverses the metabolic syndrome in premenopausal women. J Am Coll Nutr 2005;24:486-93.
12. Lee CMY, Huxley RR, Wildman RP, Woodward M. Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: A meta-analysis. J Clin Epidemiol 2008;61:646-53.
13. Tutunchi H, Ebrahimi-Mameghani M, Ostadrahimi A, Asghari-Jafarabadi M. What are the optimal cut-off points of anthropometric indices for prediction of overweight and obesity? Predictive validity of waist circumference, waist-to-hip and waist-to-height ratios. Health Promot Perspect 2020;10:142.
14. Amirabdollahian F, Haghighatdoost F. Anthropometric indicators of adiposity related to body weight and body shape as cardiometabolic risk predictors in British young adults: Superiority of waist-to-height ratio. J Obes 2018;2018:8370304. doi: 10.1155/2018/8370304.
15. Lu Y, Liu S, Qiao Y, Li G, Wu Y, Ke C. Waist-to-height ratio, waist circumference, body mass index, waist divided by height0. 5 and the risk of cardiometabolic multimorbidity: A national longitudinal cohort study. Nutr Metab Cardiovasc Dis 2021;31:2644-51.
16. Thomas DM, Bredlau C, Bosy-Westphal A, Mueller M, Shen W, Gallagher D, *et al*. Relationships between body roundness with body fat and visceral adipose tissue emerging from a new geometrical model. Obesity 2013;21:2264-71.
17. Bozorgmanesh M, Sardarinia M, Hajsheikholeslami F, Azizi F, Hadaegh F. CVD-predictive performances of "a body shape index" versus simple anthropometric measures: Tehran lipid and glucose study. Eur J Nutr 2016;55:147-57.
18. Wu L, Zhu W, Qiao Q, Huang L, Li Y, Chen L. Novel and traditional anthropometric indices for identifying metabolic syndrome in non-overweight/obese adults. Nutr Metab 2021;18:1-10.
19. Dang AK, Truong MT, Le HT, Nguyen KC, Le MB, Nguyen LT, *et al*. Anthropometric cut-off values for detecting the presence of metabolic syndrome and its multiple components among adults in Vietnam: The role of novel indices. Nutrients 2022;14:4024.
20. Yoon J, Jung D, Lee Y, Park B. The metabolic score for insulin resistance (METS-IR) as a predictor of incident ischemic heart disease: A longitudinal study among Korean without diabetes. J Pers Med 2021;11:742.
21. Guo X, Ding Q, Liang M. Evaluation of eight anthropometric indices for identification of metabolic syndrome in adults with diabetes. Diabetes Metab Syndr Obes 2021;14:1431.
22. Pourghassem Gargari B, Aliasgharzadeh A. Effect of folic acid supplementation on indices of glycemic control, insulin resistance and lipid profile in patients with type 2 diabetes mellitus. Iran J Endocrinol Metab 2011;13:354-60.
23. Haidari F, Aghamohammadi V, Mohammadshahi M, Ahmadi-Angali K, Asghari-Jafarabadi M. Whey protein supplementation reducing fasting levels of anandamide and 2-AG without weight loss in pre-menopausal women with obesity on a weight-loss diet. Trials 2020;21:1-10.
24. Liu PJ, Lou HP, Zhu YN. Screening for metabolic syndrome using an integrated continuous index consisting of waist circumference and triglyceride: A preliminary cross-sectional study. Diabetes Metab Syndr Obes 2020;13:2899.
25. Amiri P, Javid AZ, Moradi L, Haghighat N, Moradi R, Behbahani HB, *et al*. Associations between new and old anthropometric indices with type 2 diabetes mellitus and risk of metabolic complications: A cross-sectional analytical study. J Vasc Bras 2021;20:e20200236.
26. Sun J, Yang R, Zhao M, Bovet P, Xi B. Tri-Ponderal mass index as a screening tool for identifying body fat and cardiovascular risk factors in children and adolescents: A systematic review. Front Endocrinol 2021;12:694681.
27. Guerrero-Romero F, Simental-Mendía LE, González-Ortiz M, Martínez-Abundis E, Ramos-Zavala MaG, Hernández-González SO, *et al*. The product of triglycerides and glucose, a simple measure of insulin sensitivity. Comparison with the euglycemic-hyperinsulinemic clamp. J Clin Endocrinol Metab 2010;95:3347-51.
28. Song S, Son D-H, Baik S-J, Cho W-J, Lee Y-J. Triglyceride glucose-waist circumference (TyG-WC) is a reliable marker to predict non-alcoholic fatty liver disease. Biomedicines 2022;10:2251.
29. Kengne A-P, Czernichow S, Huxley R, Grobbee D, Woodward M, Neal B, *et al*. Blood pressure variables and cardiovascular risk: New findings from ADVANCE. Hypertension 2009;54:399-404.

30. Azizi F, Khalili D, Aghajani H, Esteghamati A, Hosseinpanah F, Delavari A, *et al*. Appropriate waist circumference cut-off points among Iranian adults: The first report of the Iranian National Committee of Obesity. Arch Iran Med. 2010; 13: 243-4.
31. Maleki R, Mostafazadeh M, Nazari Sharif H, Rahim Nejad S, Gorgani-Firuzjaee S. The prevalence of metabolic syndrome in air guard forces of Iran Army. Paramed Sci Military Health 2016;11:8-16.
32. Pouliot M-C, Després J-P, Lemieux S, Moorjani S, Bouchard C, Tremblay A, *et al*. Waist circumference and abdominal sagittal diameter: Best simple anthropometric indexes of abdominal visceral adipose tissue accumulation and related cardiovascular risk in men and women. Am J Cardiol 1994;73:460-8.
33. Leone A, Vizzuso S, Brambilla P, Mameli C, Ravella S, De Amicis R, *et al*. Evaluation of different adiposity indices and association with metabolic syndrome risk in obese children: Is there a winner? Int J Mol Sci 2020;21:4083.
34. Hsieh SD, Yoshinaga H. Do people with similar waist circumference share similar health risks irrespective of height? Tohoku J Exp Med 1999;188:55-60.
35. Elagizi A, Kachur S, Lavie CJ, Carbone S, Pandey A, Ortega FB, *et al*. An overview and update on obesity and the obesity paradox in cardiovascular diseases. Prog Cardiovasc Dis 2018;61:142-50.
36. Stefanescu A, Revilla L, Lopez T, Sanchez SE, Williams MA, Gelaye B. Using A Body Shape Index (ABSI) and Body Roundness Index (BRI) to predict risk of metabolic syndrome in Peruvian adults. J Int Med Res 2020;48:0300060519848854.
37. Quaye L, Owiredu WKBA, Amidu N, Dapare PPM, Adams Y. Comparative abilities of body mass index, waist circumference, abdominal volume index, body adiposity index, and Conicity index as predictive screening tools for metabolic syndrome among apparently healthy Ghanaian adults. J Obes 2019;2019:8143179.
38. Krakauer NY, Krakauer JC. A new body shape index predicts mortality hazard independently of body mass index. PloS one 2012;18:39504.
39. Haghighatdoost F, Sarrafzadegan N, Mohammadifard N, Asgary S, Boshtam M, Azadbakht L. Assessing body shape index as a risk predictor for cardiovascular diseases and metabolic syndrome among Iranian adults. Nutrition 2014;30:636-44.
40. Maessen MF, Eijsvogels TM, Verheggen RJ, Hopman MT, Verbeek AL, Vegt Fd. Entering a new era of body indices: The feasibility of a body shape index and body roundness index to identify cardiovascular health status. PLoS One 2014;9:e107212.
41. Bouchi R, Asakawa M, Ohara N, Nakano Y, Takeuchi T, Murakami M, *et al*. Indirect measure of visceral adiposity 'A Body Shape Index'(ABSI) is associated with arterial stiffness in patients with type 2 diabetes. BMJ Open Diabetes Res Care 2016;4:e000188.
42. Malara M, Kęska A, Tkaczyk J, Lutosławska G. Body shape index versus body mass index as correlates of health risk in young healthy sedentary men. J Transl Med 2015;13:1-5.
43. Dhana K, Kavousi M, Ikram MA, Tiemeier HW, Hofman A, Franco OH. Body shape index in comparison with other anthropometric measures in prediction of total and cause-specific mortality. J Epidemiol Community Health 2016;70:90-6.
44. Peterson CM, Su H, Thomas DM, Heo M, Golnabi AH, Pietrobelli A, *et al*. Tri-ponderal mass index vs body mass index in estimating body fat during adolescence. JAMA Pediatr 2017;171:629-36.
45. Wang X, Dong B, Ma J, Song Y, Zou Z, Arnold L. Role of tri-ponderal mass index in cardio-metabolic risk assessment in children and adolescents: Compared with body mass index. Int J Obes 2020;44:886-94.
46. Yang R, Liu X, Lin Z, Zhang G. Correlation study on waist circumference-triglyceride (WT) index and coronary artery scores in patients with coronary heart disease. Eur Rev Med Pharmacol Sci 2015;19:113-8.
47. Ma C-M, Lu N, Wang R, Liu X-L, Lu Q, Yin F-Z. Three novel obese indicators perform better in monitoring management of metabolic syndrome in type 2 diabetes. Sci Rep 2017;7:1-6.
48. Endukuru CK, Gaur GS, Dhanalakshmi Y, Sahoo J, Vairappan B. Cut-off values and clinical efficacy of body roundness index and other novel anthropometric indices in identifying metabolic syndrome and its components among Southern-Indian adults. Diabetol Int 2022;13:188-200.
49. Yin Q, Zheng J, Cao Y, Yan X, Zhang H. Evaluation of novel obesity and lipid-related indices as indicators for the diagnosis of metabolic syndrome and premetabolic syndrome in chinese women with polycystic ovary syndrome. Int J Endocrinol 2021;2021:7172388.
50. Adejumo EN, Adejumo AO, Azenabor A, Ekun AO, Enitan SS, Adebola OK, *et al*. Anthropometric parameter that best predict metabolic syndrome in South west Nigeria. Diabetes Metab Syndr 2019;13:48-54.
51. Bello-Chavolla OY, Almeda-Valdes P, Gomez-Velasco D, Viveros-Ruiz T, Cruz-Bautista I, Romo-Romo A, *et al*. METS-IR, a novel score to evaluate insulin sensitivity, is predictive of visceral adiposity and incident type 2 diabetes. Eur J Endocrinol 2018;178:533-44.
52. Liu XZ, Fan J, Pan SJ. METS-IR, a novel simple insulin resistance indexes, is associated with hypertension in normal-weight Chinese adults. J Clin Hypertens 2019;21:1075-81.
53. Raimi TH, Dele-Ojo BF, Dada SA, Fadare JO, Ajayi DD, Ajayi EA, *et al*. Triglyceride-glucose index and related parameters predicted metabolic syndrome in Nigerians. Metab Syndr Relat Disord 2021;19:76-82.
54. Lim J, Kim J, Koo SH, Kwon GC. Comparison of triglyceride glucose index, and related parameters to predict insulin resistance in Korean adults: An analysis of the 2007-2010 Korean National Health and Nutrition Examination Survey. PLoS One 2019;14:e0212963.
55. Zheng S, Shi S, Ren X, Han T, Li Y, Chen Y, *et al*. Triglyceride glucose-waist circumference, a novel and effective predictor of diabetes in first-degree relatives of type 2 diabetes patients: Cross-sectional and prospective cohort study. J Transl Med 2016;14:1-10.
56. Er L-K, Wu S, Chou H-H, Hsu L-A, Teng M-S, Sun Y-C, *et al*. Triglyceride glucose-body mass index is a simple and clinically useful surrogate marker for insulin resistance in nondiabetic individuals. PLoS One 2016;11:e0149731.
57. Kahn BB, Flier JS. Obesity and insulin resistance. J Clin Invest 2000;106:473-81.