

Evaluation of Eight Anthropometric Indices for Identification of Metabolic Syndrome in Adults with Diabetes

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Purpose: Several previous reports have highlighted the association between adiposity and risk of metabolic syndrome (MetS). Although it is necessary to identify which adiposity indices are best suited to identify MetS, no such study has been completed in diabetic patients. The aim of this study was to evaluate the ability of eight anthropometric indices to identify MetS in diabetic, middle-aged and elderly Chinese patients.

Patients and Methods: A cross-sectional study was conducted in 906 type 2 diabetic patients in Guangxi.

Results: The highest odds ratios for the identification of MetS were identified with CUN-BAE (OR = 28.306). The largest areas under the curve (AUCs) were observed for WHtR and BRI in men aged 40–59; CUN-BAE in men aged 60 and over; WHtR, BRI, and TyG in women aged 40–59; and BMI for women aged 60 and over. The weakest indicator for the screening of MetS in type 2 diabetes was the ABSI.

Conclusion: The most effective anthropometric indicator for the identification of MetS varied across sex and age subgroups.

Keywords: metabolic syndrome, anthropometric indices, diabetes

Introduction

Diabetes is a long-standing global health issue that increases the risk of cardiovascular complications, an important cause of death in patients with diabetes. Metabolic syndrome (MetS) is defined as the accumulation of cardiovascular risk factors such as dyslipidemia, abnormal glycemia, elevated blood pressure, and abdominal obesity. With an increasing incidence, MetS heightens the risk of cardiovascular diseases (CVDs) in type 2 diabetes.^{1–3} Early diagnosis is crucial to allow for appropriate actions to combat MetS.

Obesity is an important risk factor in the occurrence and development of several diseases,⁴ such as type 2 diabetes,⁵ MetS,^{6,7} CVDs,^{8,9} and numerous tumors.¹⁰ It is also at the core of MetS. Although some previous publications have addressed the association between adiposity and the risk of MetS, some unambiguity remains as to which obesity index is best used to diagnose MetS.¹¹ BMI is reported to be the most commonly used index to evaluate obesity,¹² Waist to height ratio (WHtR) is reported to be a good predictor of MetS in childhood,¹³ And several novel adiposity indices have been constructed recently for screening MetS, including: body roundness index (BRI),¹⁴ a body shape index (ABSI),^{15,16} conicity index (CI), Clinica

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Universidad de Navarra-body adiposity estimator (CUN-BAE),^{17–20} triponderal mass index (TMI), and triglyceride-glucose (TyG) index.^{21–24}

The relationships between classic and novel adiposity indices has not been studied in diabetic patients. Moreover, there is no consensus regarding which index is the best for identifying diabetic subjects with MetS. To our knowledge, only one previous study has been conducted in China in which the relationship between BRI and MetS was analyzed in type 2 diabetes using a small group of 585 patients.²⁵ The aim of this study was to analyze the predictive capacity of new anthropometric indices, such as the ABSI, BRI, CI, TMI, TyG, and CUN-BAE, for identifying MetS in middle-aged patients with diabetes in China. We also aimed to compare the usefulness of these new indices to that of traditional measurements such as BMI and WHtR.

Patients and Methods

Subjects

From January 2018 to December 2019, 2032 middle-aged and elderly diabetic subjects aged 40–90 years (mean 59.87 ± 8.83) were recruited in this study. Participants were from the First Affiliated Hospital of Guangxi Medical University. All the participants were of Han ethnicity and came from Southeast China. Exclusion criteria were as follows: (1) patients with infection; (2) severe CVDs, heart failure, liver cirrhosis, cancer, thyroid dysfunction, significant liver or renal impairments; (3) type 1 diabetes; (4) diabetic lactic acidosis, diabetic ketoacidosis, hyperglycemic hyperosmotic, severe fluid and electrolyte imbalance, diabetic foot, and severe diabetic nephropathy, diabetic cardio-cerebrovascular disease. Ultimately, 906 subjects (379 women and 527 men) were included. The study was approved by the Ethics Committee of the First Affiliated Hospital of Guangxi Medical University, and this study obeyed the principles of Helsinki Declaration. All subjects provided informed consent before study initiation.

Calculation of Anthropometric Indices and Adiposity Index

BMI, WHtR, CI, TyG,²⁶ CUN-BAE,²⁷ TMI,²⁸ ABSI¹⁷ and BRI¹⁴ were calculated with the following formulas:

$$\text{BMI} = \text{weight}(\text{kg}) / \text{height}^2 (\text{m}^2);$$

$$\text{WHtR} = \text{WC} (\text{cm}) / \text{height} (\text{cm});$$

$$\text{CI} = 0.109^{-1} \text{WC} (\text{m}) [\text{Weight} (\text{kg}) / \text{Height} (\text{m})]^{-1/2};$$

$$\text{ABSI} = \text{WC}(\text{m}) / \text{BMI}^{2/3}(\text{kg}/\text{m}) \times \text{height}^{1/2};$$

$$\text{BRI} = 364.2 - 365.5 [1 - \pi^{-2} \text{WC}^2 (\text{m}) \text{Height}^{-2} (\text{m})]^{1/2};$$

$$\text{TMI} = \text{Weight} (\text{kg}) / \text{Height}^3 (\text{m}).$$

CUN-BAE

This index was recommended by Gomez-Ambrosi²⁷ to estimate body fat with the following formula: $-44.988 + (0.503 \times \text{age}) + (10.689 \times \text{gender}) + (3.172 \times \text{BMI}) - (0.026 \times \text{BMI}^2) + (0.181 \times \text{BMI} \times \text{gender}) - (0.02 \text{BMI} \times \text{age}) - (0.005 \times \text{BMI}^2 \times \text{gender}) + (0.00021 \times \text{BMI}^2 \times \text{age})$ where age was in years, and gender was coded as zero for males and one for females.

TyG

The TyG index was calculated with the following formula $\text{Ln}[\text{fasting triglycerides} (\text{mg}/\text{dL}) \times \text{fasting glucose} (\text{mg}/\text{dL})/2]$.²⁶

Definition of Metabolic Syndrome

MetS was defined as per the Chinese Diabetes Society. Participants had to accord with any three or more of five factors: 1) WC ≥ 90 cm (males) and 85 cm (females), 2) FPG ≥ 6.1 mmol/L or 2-hour PG levels ≥ 7.8 mmol/L after a 75-goral glucose-tolerance test or have been diagnosed with diabetes, 3) blood pressure $\geq 130/85$ mmHg or had been diagnosed with hypertension, 4) TG ≥ 1.7 mmol/L, and 5) HDL-c < 1.04 mmol/L.

Data Collection

The homeostasis model assessment of insulin resistance (HOMA-IR) index was obtained by the program HOMA Calculator v2.2.2.²⁹ The smoking status and alcohol drinking were obtained from hospitalizations. Two options (yes/no) were used for smoking and drinking (no means never smoking/drinking, yes means current or former smoking/drinking). The participants who smoked cigarettes or drunk during the study were classified as current smokers or drinkers, and those who had not smoked or drunk for 6 months were classified as former smokers or drinkers.

Anthropometric Measures and Blood Pressure

Anthropometric measurements were performed following standardized procedures by well-trained nurses and physicians. Height and weight were measured in light clothing without shoes, using a digital scale with a precision of 1 cm and 1kg. WC was measured using a tape measure

placed halfway between the lower border of the ribs and the iliac crest in a horizontal plane at the end of normal expiration and measured to the nearest 1 cm.

After 10 minutes of rest, systolic and diastolic blood pressure were measured for 2 times from the right and left arm of the participants in the seated position, using a manometer (Reister) cuff and stethoscope (Reister). The average of Systolic and diastolic blood pressure was calculated for the statistical analysis.

Biochemical Factors

Total cholesterol (TC), Triglyceride (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-c), low-density lipoprotein cholesterol (LDL-c), fasting glucose, C peptide, glycosylated hemoglobin (HbA1C) was originated from hospitalizations. After 8–12 hours of fasting, blood samples were collected from the ante-brachial vein. These biochemical indices were measured by professional laboratory scientific officers of the First Affiliated Hospital of Guangxi Medical University.

Statistical Analysis

Continuous variables followed a normal distribution and are expressed as mean \pm standard deviation (SD). Discrete variables are expressed as percentage and frequency. Comparisons between different subgroups were analyzed using one-way analysis of variance (ANOVA) tests for normally distributed continuous variables. Mann–Whitney *U*-tests were used for highly skewed variables. All categorical variables are presented as numbers and proportions. Chi-square and Fisher's exact tests were calculated for analysis of proportion. The Spearman correlation coefficient was used to measure the correlation. Quartiles of BMI, WHtR, TMI, CI, BRI, ABSI, TyG, and CUN-BAE were calculated. Logistic regression models adjusted for sex and age were applied to estimate the odds ratio. The lowest quartiles were set as reference. Receiver operating characteristic (ROC) analyses were used to assess the feasibility of the eight obesity indices to predict MetS. Statistical analyses were completed using SPSS software (version 23.0 for windows; SPSS, Chicago, IL, USA). The ROC analysis was performed using MedCalc version 12.0 for Windows (MedCalc Software, Mariakerke, Belgium). *P* values less than 0.05 were considered statistically significant.

Results

Characteristics of the Study Subjects

Baseline characteristics of study participants were stratified by biological sex and are presented in Table 1, which shows the anthropometric measurements and biochemical parameters of the recruited diabetic patients. The average age of the participants was 59.88 ± 8.33 years for men and 55.54 ± 5.35 years for women. The average BMI was 24.58 in the subject group. Of the total participants, 35.4% were overweight (BMI = 25.0–29.9 kg/m²), 7.6% were obese (BMI \geq 30.0 kg/m²), and 68.9% had detectable MetS (Table 2).

For anthropometric indices, BMI, WHtR, ABSI, BRI, CI, CUN-BAE, TMI, and TyG were higher in patients with MetS than those without MetS (all *P* < 0.05). Participants with MetS were more likely to have a history of hypertension and nonalcoholic fatty liver disease (NAFLD) compared to those without MetS (*P* < 0.001). Diabetic patients with MetS had higher systolic and diastolic blood pressure (SBP and DBP), mass, WC, and triglyceride (TG) levels, and lower high-density lipoprotein cholesterol (HDL-c) compared to those without MetS (all *P* < 0.05). No differences were observed for fasting plasma glucose (FPG), age, or C-peptide in participants with and without MetS, across both sexes (all *P* > 0.05). Diabetic patients with MetS had higher low-density lipoprotein cholesterol (LDL-c) and insulin resistance (IR) compared to those without MetS, and total cholesterol (TC) was lower in women.

Correlations of Different Adiposity Indices and MetS Components

For all subjects, BMI was most strongly correlated with TMI in all subjects (*r* = 0.953 males; *r* = 0.966 females; Figure 1). CUN-BAE was most strongly correlated with BMI in males (*r* = 0.955; *P* < 0.001), whereas TMI was most strongly correlated with BMI in females (*r* = 0.966; *P* < 0.001). WHtR and BRI were strongly correlated with one another in both sex groups (*r* = 1; *P* < 0.001). ABSI and CI were also strongly correlated (*r* = 0.898; *r* = 0.911). BMI showed the strongest correlation with CUN-BAE in both sexes (*r* = 0.955 males; *r* = 0.949 females). TMI was most strongly correlated with mass in females (*r* = 0.772), and with WC in males (*r* = 0.757). Variables that correlate with mass also correlate with WC. IR and fasting C-peptide were most frequently correlated with all anthropometric indices, except for indicators concluded in the formula.

Table 1 Baseline Characteristics of the Study Population Stratified by Gender

Characteristics	Males			Females		
	Non-MetS Me (Q1-Q3)	MetS Me (Q1-Q3)	P value	Non-MetS Me (Q1-Q3)	MetS Me (Q1-Q3)	P value
Age (years)	58.00 (52.60–64.65)	56.54 (52.52–64.19)	0.841	60.56 (54.50–68.00)	61.29 (53.80–68.38)	0.914
Height (m)	1.6587 (1.6141–1.7032)	1.6760 (1.6349–1.7099)	0.018	1.5469 (1.5108–1.5848)	1.5494 (1.5068–1.5862)	0.868
Weight (kg)	61.10 (54.50–68.00)	71.18 (65.38–78.22)	<0.001	51.91 (46.71–59.25)	60.08 (54.65–66.70)	<0.001
WC (cm)	82.67 (76.92–86.79)	93.558 (9.89–98.65)	<0.001	80.43- (76.09–87.25)	89.83 (54.65–66.70)	<0.001
TC (mmol/L)	4.6725 (3.9300–5.3575)	4.6900 (3.9567–5.4883)	0.798	5.1050 (4.1000–5.9700)	4.8250 (3.7567–5.5967)	0.013
TG (mmol/L)	1.0467 (0.7567–1.3450)	1.7720 (1.1525–2.4288)	<0.001	1.0867 (0.8258–1.4825)	1.8260 (1.2075–2.3888)	<0.001
HDL-C (mmol/L)	1.1050 (0.9750–1.2763)	0.9279 (0.8003–1.0523)	<0.001	1.2450 (1.0850–1.4367)	0.950 (0.8441–1.0917)	<0.001
LDL-C (mmol/L)	2.8433 (2.2433–3.4300)	2.7967 (2.2590–3.3942)	0.578	3.2080 (2.2200–3.9200)	2.7900 (2.0563–3.4825)	0.009
FPG (mmol/L)	6.3800 (4.9625–8.1550)	6.6450 (5.3850–8.1850)	0.09	6.7200 (5.2833–8.5875)	7.1500 (5.8000–8.5300)	0.478
C peptide	1.1000 (0.4700–1.8750)	1.8467 (0.9533–2.7550)	<0.001	1.580 (0.6575–2.4775)	2.1467 (1.1050–3.0000)	0.001
HOMA-IR	1.09585 (0.55898–1.91939)	1.994 (0.98496–3.65000)	<0.001	1.58677 (0.57571–2.78122)	2.29358- (1.28335–4.31196)	0.005
HbA1C	8.9800 (7.1875–11.3833)	8.8000 (7.2056–11.0500)	0.393	8.7000 (6.9417–11.3100)	8.7667- (7.2286–0.7750)	0.937
SBP (mmHg)	127.3333 (114.4444–137.9286)	137.5882 (126.4375–149.208)	<0.001	132.00006.9417–11.3100)	142.3000- (127.5556–153.4545)	<0.001
DBP (mmHg)	76.4545 (65.9500–85.0417)	83.4211 (76.0000–90.3704)	<0.001	73.0625 (66.8000–80.3333)	77.6364- (69.3846–85.8571)	0.002
BMI (kg/m ²)	22.7204 (19.9350–23.7234)	25.5627 (23.8618–27.2817)-	<0.001	21.7865 (66.8000–80.3333)	25.2521- (23.0531–27.3351)	<0.001
BRI	3.3220 (2.6369–3.8512)	4.5447 (3.9950–5.2164)-	<0.001	3.9532 (3.1223–4.6841)	5.0855- (4.1380–5.7821)	<0.001
TMI	13.6340 (12.1307–14.5990)	15.2771 (14.2102–16.4192)	<0.001	14.189712.9227–15.5519)	16.1947- (4.1380–5.7821)	<0.001
CUN-BAE	22.5528 (19.5087–24.8790)	26.6641 (24.3195–29.0073)	<0.001	34.586932.0035–37.1988)	38.8179 (35.7602–41.5011)	<0.001
TyG	4.6181 (4.4496–4.8334)	4.9117 (4.6722–5.1480)	<0.001	4.7019 (4.4756–4.9097)	4.9199 (4.6998–5.2118)	<0.001
WHR	0.4978 (0.4596–0.5253)	0.5593 (0.5325–0.5903)	<0.001	0.5304 (0.487–0.5659)	0.5844- (0.5396–0.6151)	<0.001

(Continued)

Table 1 (Continued).

Characteristics	Males			Females		
	Non-MetS Me (Q1–Q3)	MetS Me (Q1–Q3)	P value	Non-MetS Me (Q1–Q3)	MetS Me (Q1–Q3)	P value
CI ($m^{2/3}/kg^{1/2}$)	1.2572 (1.2038–1.2930)	1.3156 (1.2667–1.3519)	<0.001	1.2805 (1.2255–1.3349)	1.3149- (1.2679–1.3684)	0.003
ABSI ($m^{7/6}/kg^{2/3}$)	0.0820 (0.0786–0.08480)	0.0831 (0.0800–0.0858)	0.047	0.0835 (0.0797–0.0877)	0.0839- (0.0811–0.0871)	0.589

Abbreviations: WC, waist circumference; TG, triglyceride; TC, total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; FBG, fasting blood-glucose; HOMA-IR, homeostasis model assessment of insulin resistance; HbA1C, glycosylated haemoglobin; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; WHtR, waist-to-height ratio; CI, conicity index; BRI, body roundness index; ABSI, a body shape index; TMI, triponderal mass index; TyG, triglyceride glucose index; CUN-BAE, Clínica Universidad de Navarra—body adiposity estimator.

Table 2 Components of Metabolic Syndrome, NAFLD and Lifestyle Habits in the Subject Groups

		Total (N)	Proportion (%)	Males (N)	Proportion (%)	Females(N)	Proportion (%)	P value
Smoking	No	644	70.9	269	51	375	98.9	<0.001
	Yes	262	28.9	258	49	4	1.1	
Drinking	No	644	70.9	270	51.2	374	98.7	<0.001
	Yes	262	28.9	257	48.8	5	1.3	
NAFLD	No	501	55.2	302	57.3	199	52.5	<0.001
	Yes	403	44.4	225	42.7	178	47	
MetS	No	277	30.5	141	26.8	136	35.9	<0.001
	Yes	626	68.9	384	72.9	242	63.9	
Elevated BP	No	403	44.4	245	46.5	158	41.7	<0.001
	Yes	503	55.4	282	53.5	221	58.3	
TG	No	505	55.6	287	54.5	218	57.5	<0.001
	Yes	346	38.1	205	38.9	141	37.2	
Abdominal obesity	No	238	26.2	138	26.2	100	26.4	<0.001
	Yes	367	40.4	210	39.8	157	41.4	
HDL-C	No	376	41.4	191	36.2	185	48.8	<0.001
	Yes	474	52.2	303	57.5	171	45.1	

Abbreviations: N, number of participants; MetS, metabolic syndrome; NAFLD, non-alcoholic fatty liver disease; HDL-C, high-density lipoproteins; TG, triglycerides; BP, blood pressure.

Odds Ratios and 95% Confidence Intervals of Various Obesity Indices for MetS

Binary logistic regression analysis showed that the eight anthropometric measurements included in the study were independently associated with MetS risk, even after adjustment for age, sex and history of smoking and drinking (Table 3A and B). Participants in

the highest quartile of obesity indices showed the highest risk for developing MetS, compared to those in the lower quartile. The odds ratios grew in models adjusted for age, sex, smoking, and alcohol consumption along with quartiles for all analyzed anthropometric indices, except ABSI and CI. The highest odds ratios for the occurrence of MetS were noted for WHtR (OR = 22.045; $P < 0.001$) and BMI (OR = 16.09; $P < 0.001$).

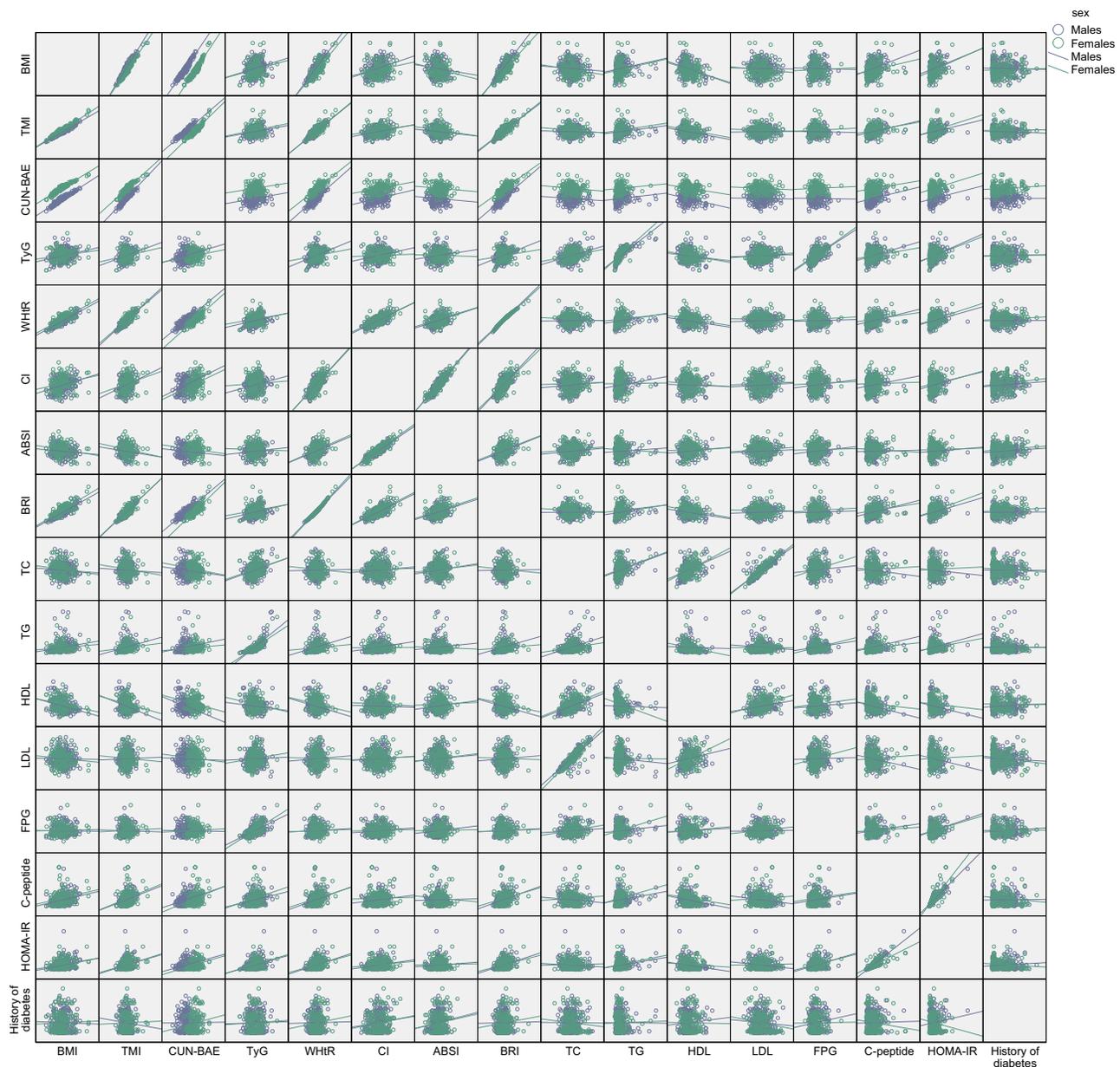


Figure 1 Correlations of different adiposity indices and MetS components stratified by gender.

Abbreviations: WC, waist circumference; TG, triglyceride; TC, total cholesterol; HDL-c, high-density lipoprotein cholesterol; LDL-c, low-density lipoprotein cholesterol; FBG, fasting blood-glucose; HOMA-IR, homeostasis model assessment of insulin resistance; HbA1C, glycosylated haemoglobin; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; WHtR, waist-to-height ratio; CI, conicity index; BRI, body roundness index; ABSI, a body shape index; TMI, triponderal mass index; TyG, triglyceride glucose index; CUN-BAE, Clinica Universidad de Navarra—body adiposity estimator.

Capacity of the Adiposity Indices to Predict MetS Using ROC Analysis

The ROC analysis revealed that, with the exception of ABSI, all obesity indices included in the study were able to discriminate between patients with and without MetS (AUCs > 0.6, $P < 0.05$) (Table 4A and B, Figure 2). In male diabetic patients aged 40–59 years, WHtR and BRI (0.892) showed the highest AUC; in females, TyG (0.731) also showed high

AUC. For patients over age 60, CUN-BAE (0.870) and BMI (0.795) had the highest AUC values in men and women, respectively, for discriminating between patients with and without MetS. WHtR and BRI had the same AUC values; the similarity in the predictive feasibility may be explained by the correlation between these two indices.

It is obvious that CUN-BAE exhibited the highest odds ratio for MetS. However, WHtR and BRI had the highest

Table 3 A: Quartiles of Different Anthropometric Indices. **B:** Odds Ratios and 95% Confidence Intervals for MetS After Adjustment for Age, Sex and History of Smoking and Drinking

A								
Quartile (%)	BMI	WHtR	CI	BRI	ABSI	TMI	TyG	CUN-BAE
25	22.3081	50.9647	125.1058	10.4325	8.0065	13.7084	4.5966	24.8653
50	24.366	55.2632	130.2191	11.4675	8.3131	15.0592	4.8422	29.3701
75	26.617	59.2593	134.9548	12.7112	8.609	16.4748	5.0919	36.0991
B								
Quartile	BMI	WHtR	CI	BRI	ABSI	TMI	TyG	CUN-BAE
1 (reference)								
2	2.654 (1.796–3.922)**	2.806 (1.708–4.609)**	1.6 (1.987–2.6311)	2.687 (1.951–5.489)**	1.823 (1.085–3.063)*	2.612 (1.749–3.902)**	1.87 (1.250–2.799)*	2.942 (1.694–5.107)
3	8.390 (5.300–13.280)**	8.216 (4.623–14.602)**	3.262 (1.949–5.461)**	8197 (3.760–12.042)**	1.806 (1.077–3.031)*	7.431 (4.773–11.571)**	3.841 (2.484–5.940)**	7.956 (4.435–14.272)**
4	16.090 (9.391–27.567)**	22.045 (10.824–44.900)	5.424 (3.015–9.759)**	21.953 (7.985–30.287)**	1.739 (1.032–2.929)*	15.88 (9.352–26.965)**	9.77 (5.706–16.728)**	28.306 (13.549–59.133)**

Notes: A.**p<0.001. B.*p<0.05.

Abbreviations: CI, confidence interval; BMI, body mass index; WHtR, waist-to-height ratio; CI, conicity index; BRI, body roundness index; ABSI, a body shape index; TMI, triponderal mass index; TyG, triglyceride glucose index; CUN-BAE, Clínica Universidad de Navarra—body adiposity estimator.

AUC values in male patients aged 40–59 years for discriminating between patients with and without MetS. This may be explained by the statistical methods used and by the different age group. The WHtR index had the highest Youden index values in men aged 40–59 (0.54) and over 60 (0.425), whereas for females, BMI (0.41) and CUN-BAE (0.51) showed the highest values.

The cut-off values of the optimal adiposity indices were as follows: 0.870 for CUN-BAE in men over age 60; 0.5238 for WHtR and 3.8215 for BRI in men aged 40–59; 0.5664 for WHtR, 4.6966 for BRI, and 4.733 for TyG in women aged 40–59; and 22.8129 for BMI in women over age 60.

Discussion

There have been various conclusions drawn about the feasibility of anthropometric indexes in identifying metabolic and obesity disorders. Khader et al recommended WHtR as a diagnostic index for metabolic disorders. However, none of the included anthropometric indices (BMI, WC, and WHtR) was better than the others, as was also found in studies conducted in Spanish population. This study indicated that all obesity indices had a similar capacity to predict MetS. However,

when the subjects were stratified by biological sex, BMI showed the largest AUC in men, whereas WHtR and BRI in women.^{30,31} Davila-Batista concluded that CUN-BAE was the best indices for the evaluation of individuals with MetS. In the Chinese population, the best predictors of MetS were reported to be BRI and WHtR.³² In a study of the Polish population, logistic regression analysis yielded the same results as ROC curve analysis, showing that WHtR, BRI and CUN-BAE were the best anthropometric indices to identify MetS in men and women (separately) in the Polish population. Previous studies in Asian adults^{30,31} or in obese adolescents^{30,31} have shown WHtR to have greater feasibility for diagnosing subjects with MetS; CUN-BAE and ABSI were not included in these indices. In a Women's Health Initiative Study³² of 2672 postmenopausal females, BMI was shown to have greater predictive feasibility than WHtR. The variation across these studies may largely depend on sex,³³ ethnicity,^{34,35} disease,^{36,37} and age of participants,³⁸ as well as the anthropometric indices selected for analysis.

We think that this study is the first to explore and compare the MetS predictive capacity of the eight obesity indexes which evaluate general (BMI), abdominal (CI,

Table 4 AUC (95% CI) of Different Obesity Indices in Diagnosis of MetS Stratified by Age and Gender

A									
Adiposity Indices (Females)	AUC	AUC (95% CI)		P value	Cut-Off	Sensitivity (%)	Specificity (%)	Youden Index	Z
40–59									
BMI	0.693	0.58	0.807	0.001	>22.9398	76.1	65.1	0.4123	5.255
WHtR	0.731	0.625	0.838	<0.001	>0.5664	12.8	94.7	0.3812	3.797
CI	0.677	0.566	0.788	0.003	>1.2707	65.4	65.8	0.3117	2.067
ABSI	0.593	0.47	0.715	0.126	>0.0802	76.9	44.7	0.2166	0.561
BRI	0.731	0.625	0.838	<0.001	>4.6966	51.3	86.8	0.3812	3.797
TMI	0.689	0.578	0.801	0.002	>14.5224	73.4	65.1	0.3847	5.183
CUN-BAE	0.68	0.568	0.793	0.003	>34.8267	72.5	68.3	0.4073	5.094
TyG	0.731	0.628	0.834	<0.001	>4.733	69.9	63.2	0.3306	5.106
≥60									
BMI	0.795	0.716	0.875	<0.001	>22.8129	81.8	65.3	0.471	9.758
WHtR	0.772	0.687	0.858	<0.001	>0.5548	79.6	68	0.4757	6.764
CI	0.631	0.527	0.735	0.015	>1.3369	53.8	74	0.2776	2.425
ABSI	0.523	0.414	0.631	0.672	>0.0814	78.5	34	0.1249	0.367
BRI	0.773	0.687	0.858	<0.001	>4.4512	82.8	62	0.4757	6.768
TMI	0.777	0.694	0.86	<0.001	>15.0772	75.8	72.2	0.4798	9.528
CUN-BAE	0.793	0.712	0.873	<0.001	>36.8256	80.3	70.8	0.5114	9.669
TyG	0.741	0.653	0.828	<0.001	>4.853	72.4	57.6	0.337	5.194
B									
Adiposity Indices (Males)	AUC	AUC (95% CI)		P value	Cut-Off	Sensitivity (%)	Specificity (%)	Youden Index	Z
40–59									
BMI	0.876	0.81	0.941	<0.001	>23.6203	80.3	76.4	0.5666	11.28
WHtR	0.892	0.83	0.955	<0.001	>0.5238	83.9	87.2	0.7105	12.14
CI	0.769	0.68	0.858	<0.001	>1.2729	74.8	73.7	0.4852	6.435
ABSI	0.603	0.492	0.714	0.064	>0.0796	76.8	44.7	0.2151	1.954
BRI	0.892	0.83	0.955	<0.001	>3.8215	83.9	85.7	0.7105	9.371
TMI	0.869	0.804	0.933	<0.001	>14.1602	78.4	75	0.5344	10.93
CUN-BAE	0.875	0.81	0.94	<0.001	>23.1473	83	76.4	0.5942	11.47
TyG	0.777	0.699	0.856	<0.001	>4.8422	66.2	81.4	0.4761	9.094
≥60									
BMI	0.864	0.794	0.935	<0.001	>23.8281	71.2	80	0.5125	8.717
WHtR	0.818	0.741	0.895	<0.001	>0.5460	66.4	88.4	0.5473	8.072
CI	0.715	0.741	0.895	<0.001	>1.2866	70.1	73.8	0.439	4.026
ABSI	0.582	0.621	0.81	0.14	>0.0836	49.5	66.7	0.162	1.24
BRI	0.818	0.476	0.688	<0.001	>4.2691	66.4	87.1	0.5473	8.068
TMI	0.817	0.737	0.897	<0.001	>14.9358	57.5	84.6	0.4212	7.347
CUN-BAE	0.87	0.799	0.94	<0.001	>26.1304	64.4	87.7	0.5207	9.259
TyG	0.644	0.539	0.749	0.009	>4.7352	59.1	67.8	0.2686	3.679

Abbreviations: CI, confidence interval; BMI body mass index; WHtR waist-to-height ratio; CI, conicity index; BRI, body roundness index; ABSI, a body shape index; TMI, triponderal mass index; TyG, triglyceride glucose index; CUN-BAE, Clínica Universidad de Navarra—body adiposity estimator.

WHtR), and visceral (BRI, ABSI) obesity, as well as three newly devised indices (TyG, CUN-BAE, and TMI) among Chinese diabetes patients. Our study suggested that all

these indexes were significantly associated with MetS following adjustment for sex, age, and history of drinking and smoking.

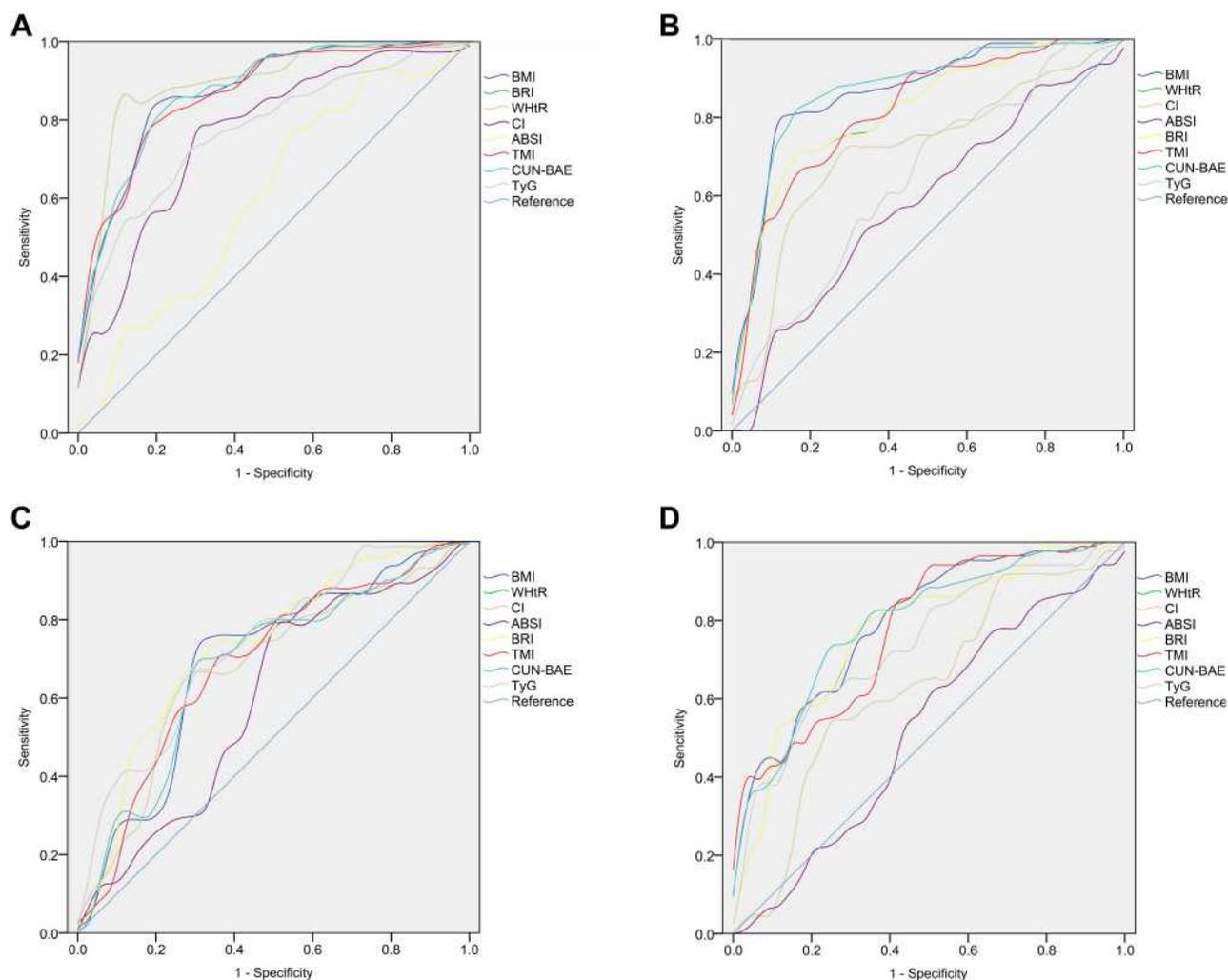


Figure 2 ROC curves for different obesity indices used to identify the presence of MetS in type 2 diabetes stratified by gender and age.

Notes: (A) Males aged 40–69; (B) males aged 60 and over; (C) females aged 40–69; (D) females aged 60 and over.

Abbreviations: BMI, body mass index; WHtR, waist-to-height ratio; CI, conicity index; BRI, body roundness index; ABSI, a body shape index; TMI, triponderal mass index; TyG, triglyceride glucose index; CUN-BAE, Clínica Universidad de Navarra—body adiposity estimator.

In this study, ROC analyses were performed and in patients aged 40–59 years the index with the largest AUC was WHtR, in both sexes. Similar results have previously been reported, demonstrating that WHtR can predict MetS better than BMI.^{39–44} The underlying mechanism may be related to the fact that WHtR takes height into consideration, which allows for better consideration of central adiposity. Thus, WHtR has the potential to serve as a prediction index for MetS in Chinese adults. Moreover, WHtR has several advantages including low cost, ease of use, common use in both men and women, and previous applications in various populations.

In this analysis, the largest AUC from ROC analyses and highest odds ratio in men aged over 60 was for CUN-BAE. Gomes Marcos also considered that the index with

the highest odds ratio of MetS was CUN-BAE, according to their analysis. It is important to consider that CUN-BAE evaluates body fat content, and high values increase the risk for obesity complications.^{45,46} Previous studies suggest that MetS can be better predicted using body fat percentage.^{47,48} Although the CUN-BAE formula is based on BMI, this new index has an advantage because it also takes age and sex of subjects into consideration. Vinknes has also reported that CUN-BAE is a better index than BMI for prediction of MetS.⁴⁹

Several previous reports have detailed the limitations of BMI,^{50–52} because this index cannot distinguish between muscle mass and body fat, and it has no ability to accurately reflect body fat distribution. In agreement with other previous reports,^{53,54} our findings suggested

that, when compared with other measurements, BMI showed improved accuracy, reliability, cost-effectiveness, and precision.

ABSI was the only index that did not perform well and was the weakest predictor of MetS in our study. Previous studies have reported similar findings, where the lowest AUC or the lowest odds ratio for MetS was with ABSI.^{18,55–57} Only a few studies suggest that the ABSI may be more useful than the classical adiposity indices.¹⁸ In the Spanish population, ABSI was reported to be as a better MetS risk indicator in men.⁴⁰ A study conducted in China also indicated that ABSI was the best measurement for estimating MetS risk in males.⁵⁸ ABSI can estimate body shape regardless of body size, and thus, this index allows for better prediction of premature mortality than the traditional adiposity indices.⁵¹ Several studies have also indicated that ABSI performs better than WHtR and BMI as an adiposity measurement to predict metabolic diseases.^{59–61} These inconsistencies between our study and others may be explained by different end point variables, a different subject characteristic. For example, subject height was 1.69 meters in the study by Krakauer,¹⁷ but was 1.61 meters in the present study. Thus, we postulate that height may play a role in the feasibility of ABSI to identify MetS.

The CI index formula includes height, weight, and abdomen circumference and has been demonstrated to be an equal indicator to WHtR.⁶² Compared with WHtR, CI has several advantages; an adjustment of WC for height and weight is included with a theoretical range; abdominal adiposity is compared directly; and fat distribution is assessed without hip circumference. A previous study identified CI as the most useful predictor of cardiovascular events among adiposity indices.⁶³ However, a Heart Study found that CI was not a better index compared with classical measurements for predicting CVDs.⁶⁴ Our study identified CI as an inferior predictor for MetS compared with BMI, BRI and WHtR, which is in agreement with other studies conducted within the Chinese population.^{65,66} These conflicting reports may be explained by differing ethnicity and other features of study subjects, and by overall study size.

BRI has been used as a novel measurement of body fat and visceral obesity.^{14,61} This study indicated that though BRI was able to identify MetS, it did not show better predictive capacity compared to other indices. In previous studies, BRI and WHtR were reported to have the same predictive power (identical areas under the ROC curve),

which is in agreement with the findings in our study.^{51,67,68} Some previous reports have demonstrated a potential for BRI to identify MetS and its components,^{67,69,70} while other studies have reported that BRI is not better at identifying MetS than traditional indicators such as BMI and WHtR.^{67,69,71–73}

Zhang also reported that the capacity of BRI to identify subjects with MetS was equivalent to that of other indices.⁴¹ Several similar results have been reported in postmenopausal women, as well as in obese and overweight adults.^{53,72,73}

Our study has several merits, but was not without limitation. The participants in this study created a homogeneous sample, coming from the same location with the same lifestyle, culture, and eating habits. Importantly, study participants were grouped by biological sex and age, and this was the first study to compare the efficacy of eight adiposity indices for identifying MetS in patients with diabetes.

However, because this study included a self-selected sample of Asian patients, the findings were not applicable to the general population or to other age groups of different regions. Additional studies are needed to confirm our findings.

Conclusion

With the exception of ABSI, other anthropometric indices may be useful in a clinical setting to identify subjects with diabetes. WHtR was found to be useful in identifying MetS and is simple to use. Therefore, we recommend WHtR be used as a screening tool to identify patients at high risk of MetS. ABSI was the weakest indicator of MetS. For elderly patients (aged 60 and over), CUN-BAE may serve as an alternative index to BMI for identification of MetS.

Disclosure

The authors report no conflicts of interest in this work.

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